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Technologies for the Detection and Monitoring of Clandestine Underground Tunnels

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Table of Contents

TABLE OF CONTENTS	I
TABLES.....	IV
FIGURES.....	IV
ACRONYMS.....	V
INTRODUCTION.....	1
THE HISTORICAL USE OF CLANDESTINE UNDERGROUND TUNNELS.....	4
TUNNELS IN WORLD WAR II	4
TUNNELS IN KOREA.....	5
TUNNELS IN VIETNAM	6
AN OVERVIEW OF CONDITIONS AT UNITED STATES BORDERS	8
DOMESTIC DEPARTMENTAL OVERVIEW	8
DEPARTMENT OF HOMELAND SECURITY – DHS	10
DEPARTMENT OF DEFENSE - DoD	11
DEPARTMENT OF JUSTICE – DOJ	13
OTHER AGENCIES AND PROCEDURES	14
POLITICAL AND GEOGRAPHIC BORDER CHARACTERISTICS	15
POLITICAL ENVIRONMENT PRE- 9/11	17
U.S. – MEXICO PRE-9/11	17
U.S. – CANADA PRE-9/11	18
NAFTA	20
SECURITY CONDITIONS, PRE-9/11	21
BORDER SECURITY POST-9/11.....	22
BI-NATIONAL AND INTERAGENCY COOPERATION FOR BORDER SECURITY	23
SECURE BORDER INITIATIVE (SBI)	26
TUNNELS ON UNITED STATES BORDERS, TO THE PRESENT	27
THE SEVENTY-ONE TUNNELS	28
DRUG TUNNELS.....	29
HUMAN SMUGGLING.....	30
TUNNEL TYPES.....	31
UNIMPROVED TUNNELS	31
IMPROVED TUNNELS	32

TUNNELS CONNECTING TO BI-NATIONAL DRAINAGE SYSTEMS	34
CONSTRUCTION METHODS & COSTS	35
GEOLOGICAL CONSTRAINTS	36
THE UNKNOWN: FUTURE TUNNELS	38
ILLEGAL ACTIVITIES	40
TERRORISM	41
TUNNEL DETECTION EFFORTS	43
U.S. PUBLIC INFORMATION EFFORTS	44
LEGISLATION AND LAWS	44
UNITED STATES.....	45
MEXICO AND CANADA.....	45
IMPEDIMENTS TO ACTION.....	46
NATIVE AMERICAN RESERVATION JURISDICTION	46
ENFORCEMENT JURISDICTION.....	48
IMMEDIATE REMEDIATION.....	48
FUNDING AND LEGISLATION.....	49
UNINTEGRATED BORDER FENCING.....	52
LOGISTICS OF TUNNEL DETECTION TRAINING	52
 OVERVIEW OF TUNNEL DETECTION TECHNOLOGIES	 54
 TECHNOLOGY SELECTION METHODOLOGY	 54
SENSING DEPTH	55
PRECISION & ACCURACY OF OUTPUT.....	55
COST.....	56
EASE OF DEPLOYMENT	56
SENSOR TYPES & APPLICABILITY.....	56
GRAVITY SURVEYING	57
RESISTIVITY	59
ACTIVE SEISMIC SURVEYING.....	60
PASSIVE SEISMIC SURVEYING.....	62
GROUND PENETRATING RADAR.....	63
ELECTROMAGNETIC INDUCTION	65
MOTION DETECTORS.....	66
DEPLOYMENT PLATFORMS & OPTIONS.....	68
TUNNEL RISK LEVEL.....	69
COST.....	69
SURVEILLANCE AREA	70
ADAPTABILITY	71
DATA HANDLING	71
QUALITY OF INFORMATION (QOI) CRITERIA	71
SECURITY	74
TRANSMISSION	75
ANALYSIS & FUSION.....	77
MONITORING & VERIFICATION.....	78
 RECOMMENDATIONS.....	 79
 TECHNOLOGY COMBINATION	 79

TUNNELING RISK LEVEL	79
SUBSURFACE SENSING SOLUTIONS.....	82
MOTION SENSING SOLUTIONS	87
RECOMMENDED DEPLOYMENT STRATEGY	88
IMPLEMENTATION	91
PHASE 1	91
PHASE 2	92
PMESII SUPPORT FOR RECOMMENDED TECHNOLOGIES.....	93
POLITICAL	93
MILITARY	98
ECONOMICS	98
SOCIAL	100
INFORMATION	102
INFRASTRUCTURE – BORDER FENCING.....	105
 <u>APPLICATION OF TECHNOLOGIES TO ALTERNATE REGIONS.....</u>	 <u>107</u>
 CURRENT INTERESTS ABROAD	 107
IRAQ	107
AFGHANISTAN.....	108
EGYPT (GAZA STRIP)	109
COLOMBIA.....	110
TECHNOLOGY IMPLICATIONS.....	111
APPLICABILITY TO GEOLOGICAL AND ENVIRONMENTAL CONDITIONS	112
 <u>CALL FOR ADDITIONAL RESEARCH.....</u>	 <u>114</u>
 IMMEDIATE RESEARCH (1-2 YEARS)	 114
INTERMEDIATE RESEARCH (2-5 YEARS)	114
LONG TERM RESEARCH (OVER 5 YEARS)	115
OTHER AREAS FOR RESEARCH.....	115
 <u>CONCLUSION</u>	 <u>117</u>
 LIMITATIONS	 117
 <u>BIBLIOGRAPHY</u>	 <u>126</u>
 <u>ABOUT THE INTERNSHIP PROJECT</u>	 <u>144</u>
 <u>ABOUT THE AUTHORS</u>	 <u>145</u>

Tables

Table 1: Locations of Discovered Clandestine Tunnels	27
Table 2: Recommended Deployment Strategy	88

Figures

Figure 1: Border Patrol Sectors as of 2007	9
Figure 2: Department of Homeland Security Organizational Chart	10
Figure 3: Department of Defense Organizational Chart	11
Figure 4: Department of Justice Organizational Chart	13
Figure 5: HIDTA Headquarters and Southwest Border Regions.....	14
Figure 6: U.S.-Mexico Border Map.....	16
Figure 7: U.S.-Canada Border Map	16
Figure 8: Alternate Migrant Routes	23
Figure 9: An Unimproved Tunnel	32
Figure 10: An Improved Tunnel	33
Figure 11: Nogales Drainage System with Tunnel Connecting.....	34
Figure 12: Nogales Drainage System	35
Figure 13: Depth to Water Table, U.S.-Mexico Border Cities	38
Figure 14: Map of Arizona with Native American Indian Reservations Shown.....	47
Figure 15: Risk Assessment Output.....	80
Figure 16: Recommended Subsurface Sensing Solutions	83
Figure 17: Nogales Drainage System	87
Figure 18: Illegal Aliens Apprehended by Border Patrol in FY 2006 and 2007	106

Acronyms

AOR	Area of Responsibility
ASO	Alien Smuggling Organization
ATF	Bureau of Alcohol, Tobacco, Firearms, and Explosives
BAA	Broad Agency Announcement
BORFIC	Border Patrol Field Intelligence Center
BSET	Border Security Evaluation Teams
CASA	Center for the Analysis of Subsurface Activity
CBCF	[Canada-U.S.] Cross Border Crime Forum
CBP	Bureau of Customs and Border Protections
CBSA	Canadian Border Services Agency (Canada)
CTAC	Counterdrug Technology Assessment Center
DARPA	Defense Advanced Research Projects Agency
DEA	Drug Enforcement Agency
DHS	Department of Homeland Security
DoD	Department of Defense
DOJ	Department of Justice
DOS	Department of State
DTO	Drug Trafficking Organization
DTRA	Defense Threat Reduction Agency
EPIC	El Paso Intelligence Center
AFI	Federal Agency of Investigation (Mexico)
FBI	Federal Bureau of Investigations
FFRDC	Federally Funded Research and Development Center
GIS	Geographical Information System
GSA	Geological Society of America
HIDTA	Southwest Border High Intensity Drug Trafficking Area
HITS	High Impact Technology Solution
HSARPA	Homeland Security Advanced Research Projects Agency
IBET	International Border Enforcement Team
ICE	Immigration and Customs Enforcement
INS	Immigration and Naturalization Service (former)
JTF-North	Joint Task Force North
LEA	Law Enforcement Agency

LOC	Library of Congress
MDL	Military Demarcation Line
MLU	Mexican Liaison Units
NDIC	National Drug Intelligence Center
NGA	National Geospatial-Intelligence Agency
OCDETF	Organized Crime and Drug Enforcement Task Force (DOJ)
OFO	Office of Field Operations
ONDCP	Office of National Drug Control Policy
QoI	Quality of Information
OSHA	Occupational Safety and Health Administration
PFP	Federal Preventive Police (Mexico)
POE	Port of Entry
R & D	Research and Development
S & T	Science and Technology (DHS)
RMCP	Royal Mounted Canadian Police (Canada)
SBI	Secure Border Initiative
SENTRI	Secure Electronic Network for Travelers Rapid Inspection
SPAWAR	Space and Naval Warfare Systems Command
TNT	Trinitrofluorene
TSWG	[Tunnel Detection] Technical Support Working Group
USACE ERDC	United States Army Corps of Engineers-Engineer Research & Development Center
USBP	United States Border Patrol
USCS	United States Customs Service (former)
USGS	United States Geological Survey
USCENTCOM	United States Central Command
USNORTHCOM	United States Northern Command
USSOUTHCOM	United States Southern Command
USSTRATCOM	United States Strategic Command
WMD	Weapons of Mass Destruction

Introduction

The detection of clandestine underground tunnels, tunneling activities, and tunnel use is of strategic interest to the United States. Whether these activities and features appear on our borders, on American soil, or under U.S. interests abroad, they provide potential gateways for grave and undesirable activity interfering with said interests.

The very nature of a clandestine underground tunnel suggests such undesirable activity. Plainly, activities which are welcomed do not require clandestine action. The action of creating hidden tunnels has long been associated with activities such as prison breaks, guerilla tactics in wartime, and transfer of contraband.

In February 2007, the Homeland Security Advanced Research Projects Agency (HSARPA) published a Broad Agency Announcement BAA07-01A, a call for proposals on the detection of tunnels. The announcement emphasized the following expectations:

Successful proposals...

- ...provide “high-risk/high-payoff technologies” for potential “revolutionary rather than incremental improvements”;
- ...work toward an operational demonstration in the near-term;
- ...have the goal of rapid detection leading to wide-area surveillance and long-term deterrence.

Ideal technologies should...

- ...work seamlessly with existent commercial systems and processes;
- ...detect and locate near-surface tunnels, infrastructure, and geologic heterogeneity in the depth range of 0-100 feet;
- ...work in a variety of environmental conditions;
- ...work in the presence of natural and man-made obstacles (i.e., fences, vehicle traffic, human infrastructure, and communications);
- ...support data fusion with other technologies;

- ...minimize false alarm rates;
- ...provide accurate positioning via GPS tagged data;
- ...be automated;
- ...allow for automated data interpretation;
- ...return as much information about subsurface anomalies as possible;
- ...support existing change-detection programs.

HSARPA was prepared to fund individual proposals in the range of \$100,000 to \$3,000,000.¹

This call for proposals was driven by the asymmetric threat posed by tunnels, particularly those under United States borders. In order to both understand the threat and propose solutions for the detection and monitoring of tunnels, an examination will be made of historical tunneling concerns, U.S. borders and cross-border relations, and the known presence of cross-border tunnels on U.S. borders, as a case study. With this foundation, an exploration of available technologies will commence, to include a comparison of sensor modalities and deployment platforms. Analysis will include data handling concerns, with quality of information as the primary determiner of optimal solutions. Finally, a coherent recommendation including a combination of targeted technologies will be proposed, along with appropriate political, military, economic, social, and infrastructure and informational support for the proposed set of technologies. Alternate applications of proposed technologies will be briefly explored to maximize the value of selected assets. Finally, recommendations for additional research will be made for continued improvements of existing technologies, development of new technologies, and refinement of data analysis methods to maximize the timeliness and effectiveness of detection methods.

¹ “BAA07-01A (Tunnel Detection Technologies Project).” 22 Feb. 2007. Technology, Research, Education, and Commercialization Center. 12 Dec. 2007 <<http://www.trecc.org/cgi-bin/fundopp/viewopp?opp=BAA07-01A>>.

The analysis of tunnel detection technologies and related issues falls directly under several missions of United States Strategic Command (USSTRATCOM). First, a potentially serious consequence of undetected clandestine tunnels is the possibility of transfer of weapons of mass destruction (WMD) through said tunnels. Successfully detecting the presence of tunnels and activity within them furnishes the nation with tools to combat these potential transfers. Second, knowledge of the presence of tunnels and activity within them, whether under our borders or elsewhere, provides an additional information layer which can be fused with existing data to address activity patterns and areas of concern. This improvement in intelligence arising from improved surveillance is a key position of advocacy of USSTRATCOM. Finally, the improvement in intelligence provided by the information gathered through the fusion of tunnel data with other sources of historical and current data increases the probability of both detecting new tunnels and taking appropriate countermeasures. These facets of the tunnel detection problem and solution sets support USSTRATCOM's missions of combating WMD, enhancing intelligence data that may lead to WMD transfer, and in general, sound strategic decision-making.

The Historical Use of Clandestine Underground Tunnels

In the past, tunnels have been used for military and smuggling purposes, in addition to serving as prison escapes and living quarters. In the U.S. has had a number of specific interests in historic tunneling activities: German prisoner of war (POW) camps during World War II; tunnels under the Korean De-militarized Zone (DMZ) used for smuggling or a potential military invasion; and tunnels used by the Vietnamese during the French-Indochina; and Vietnam Wars for concealing weapons, underground guerilla warfare, and as living quarters.

Tunnels in World War II

Tunnels have frequently been used by prisoners to escape confinement, but during World War II, Allied POW's intense desperation to escape confinement in German prisons was particularly evident. Two of the most memorable tunnel escapes, the Wooden Horse Escape of October 1943 and the Great Escape of March 1944, took place at the Stalag Luft III prison camp in Sagan, Poland. This German Air Force POW camp was built in 1942. It was situated on sandy soil to prevent prisoners from tunneling. Powdery gray topsoil exposed footsteps.² Housing units were also raised above the ground on stilts so German guards could search underneath for entrances. To detect the sounds of tunnel construction, guards positioned sensitive microphones around the camp perimeter.³

In spite of barriers like perimeter trip wires, fencing, arc lighting, search lights, and guard dogs, POW's went to extreme measures to leave this prison. To decide on a location to tunnel, prisoners circumvented guard towers, built close to fences to minimize tunnel lengths, concealed entrances by digging in dark hallways or into existing drains, and hid exposed dirt.

Three prisoners successfully escaped during the Wooden Horse Escape by concealing the entrance under a wooden horse near the perimeter fence. During the Great Escape,

² Luszki, Walter A. "Beating the Underground Molders." *The Journal of Criminal Law, Criminology, and Police Science*. 48.1 (1957): 103-105.

³ Vance, Jonathan. "The War behind the Wire: The Battle to Escape from a German Prison Camp." *Journal of Contemporary History* 48.1 (1993): 675-693.

another three got away out of the seventy-six who tried; fifty of the unsuccessful people were later shot.⁴

Tunnels in Korea

Three tunnels located along the Military Demarcation Line (MDL) in the Korean DMZ were discovered by Allied troops and the South Korean Army in the 1970's. Another was found in 1990.⁵ These tunnels were built in the early 1970's well after the Korean War had ended and the subsequent Armistice Agreement that divided the Korean Peninsula into North and South Korea was signed.⁶ Their construction was ordered by Kim Il Sung, the president of the Democratic People's Republic of Korea, "who declared in 1971 that one tunnel under the DMZ was worth more than 10 nuclear weapons."⁷ He also ordered every North Korean People's Army division along the DMZ to dig and maintain at least two tunnels. Experts note that twenty to thirty more tunnels are believed to exist, but have not yet been found by the South Koreans.⁸

The primary purpose of the tunnels was to allow North Korea to stage a surprise attack or military invasion into South Korea through the buffer zone, but the potential invasion never actually occurred. The tunnels' large diameter and length of approximately 1000 meters long would have allowed for heavy equipment and armed military personnel to move across the DMZ in about an hour.⁹ An exit report that was compiled for the Eighth U.S. Army Tunnel Neutralization Team observed that the invasion tunnels were built on south-sloping hills and in terrain that would be unsuitable for employment of friendly

⁴ Carroll, Tim. *The Great Escape from Stalag Luft III: The Full Story of How 76 Allied Officers Carried Out World War II's Most Remarkable Mass Escape*. New York: Pocket Books, 2004.

⁵ United States. Foreign, Defense, and Trade Division. *North Korea: Chronology of Provocations, 1950 – 2003*. Dick K. Nanto. Washington, D.C.: Library of Congress, 2003. 18 March 2003. CRS Web. 11 Nov. 2007 <<http://www.fas.org/man/crs/RL30004.pdf>>.

⁶ Korean War. GlobalSecurity.org. 27 Nov. 2007 <<http://www.globalsecurity.org/military/ops/korea.htm>>.

⁷ Galloway, Joseph L. and Bruce B. Auster. "The Most Dangerous Place on Earth." *U.S. News and World Report* 12 June 1994. 11 Oct. 2007 <http://www.usnews.com/usnews/news/articles/940620/archive_011982_7.htm>.

⁸ "DMZ-DPRK Tunnels." GlobalSecurity.org. 12 Dec. 2007 <<http://www.globalsecurity.org/military/world/dprk/kpa-tunnels.htm>>.

⁹ Harrold, Michael. *Comrades and Strangers*. London: John Wiley & Sons, Ltd., 2004.

armor.¹⁰ Tunnel characteristics varied widely; one was reinforced with concrete, some were built in solid granite, and they ranged in depth from 50-450 meters, making detection very difficult. Some contained reinforcements like lighting, railways, and track vehicles.¹¹

Tunnels in Vietnam

The Vietnamese built tunnels for underground guerilla warfare and living quarters during the French-Indochina War (1946-1954) and Vietnam War (1955-1975). They proved to be so successful in the construction and use of the in the 1960's went undetected by U.S. troops for over three years after the beginning of the Vietnam War.

The tunnels served as strong fortresses, and were built in dry, reddish clay that was very well suited to tunneling. Surprise attacks by underground fighters were conducted from near-surface chambers and secret passages were built to manufacture and conceal weapons. The Vietnamese also hid and lived inside the tunnels during the war. Those who designed these underground facilities employed elaborate improvements and construction techniques, including ventilation, lighting, electricity, water wells, and generators. Reinforcements in the tunnels of Cu Chi, the most developed of any multi-level tunnel system, included underground hospitals, workshops, kitchens, storerooms, command posts, classrooms, and even a cinema.¹²

On September 28, 1967, a detachment of the Korean 28th Infantry Regiment of the 9th (South Korean) Division captured an enemy document, but it was not until four months later that it was given to the American Defense Intelligence Agency and U.S. commands in Vietnam so troops could act on the new intelligence. Tunnel openings were disguised from enemy detection with flowers and trees planted around tunnel exit points, but potential tunnel entrances were eventually found by U.S. soldiers. Soldiers found the

¹⁰ Hatheway, Allen W. Demilitarized Zone Invasion Tunnels; As Seen Through North Korean Eyes: Proposed Proceedings of the GSA Military Geology Symposium. Rolla, Missouri: 1998.

¹¹ Marek, Angie C. "Locking Down the Border." US News and World Report 17 June 2007. 3 Oct. 2007 <<http://www.usnews.com/usnews/news/articles/070617/25border.t.htm>>.

¹² "Cu Chi (Cu Chi Diadao) Travel Guide." 12 Dec. 2007 <[http://www.iexplore.com/attractions/Cu_Chi_Tunnels_\(Cu_Chi_Diadao\).jhtml](http://www.iexplore.com/attractions/Cu_Chi_Tunnels_(Cu_Chi_Diadao).jhtml)>.

tunnels by investigating areas with freshly-dug dirt,, gardens, stacks of bamboo, piles of feces or the smell of urine.

The Americans used spotter planes to detect thousands of tons of earth removed from the tunnels with high-resolution photography, infrared sensors, and new aerial-surveillance techniques. Troops on the ground used the “Tunnel Exploration Toolkit” which included flashlights, revolvers, and a communication system. One report indicates, “The presence of a tunnel complex within or near an area of (American) operations poses a continuing threat to all personnel in the area. No area containing tunnel complexes should ever be considered completely cleared.”¹³ Many important lessons were learned from the discovery and exploitation of Vietnamese tunnels; among them, how easily a society and its ability to use tunnels could be underestimated, and also, the importance of quickly relaying tunnel intelligence to commanders and ground personnel.

¹³ Mangold, Tom. The Tunnels of Cu Chi. New York: Random House, Inc, 1985.

An Overview of Conditions at United States Borders

The following research is an atheoretical, idiographic, single case study. The case study will focus on the U.S. borders with Mexico and Canada; more particularly, the study will identify the occurrence and threat of clandestine tunnels along the borders. This study is of least similar cases where a secure border is the desired outcome on both fronts; however, the outcome is achieved by employing different strategies on each border. The result of the case study will produce a background for technology and policy recommendations to confront the security threat posed by tunnels. While the subject does encompass broader topics (i.e. the function of borders, immigration policy, drug policy, and the War on Terror), this case study is devoted to support of technology recommendations and the socio-political measures these recommendations will require.

Domestic Departmental Overview

Several agencies are involved in tunnel detection, both in the United States and in other countries of U.S. or allied interest. These three main agencies include the Department of Homeland Security (DHS), Department of Defense (DoD), and Department of Justice (DOJ).

In the United States, DHS has the task of securing our borders and serves as the agency overseeing several agencies involved in tunnel detection and exploitation (investigation). DHS's mission is to prevent and deter terrorist attacks and protect against and respond to threats and hazards.¹⁴ Under DHS are the Customs and Border Patrol (CBP) and Immigration and Customs Enforcement (ICE). CBP's purpose is to secure the homeland on both the U.S.'s northern and southern borders; their jurisdiction in tunnel detection includes drug seizures and illegal apprehensions, in addition to other functions like admitting people and goods, enforcing trade and immigration laws, collecting fees and

¹⁴ "Strategic Plan – Securing Our Homeland." 31 Oct. 2007. United States Department of Homeland Security. 29 Nov. 2007 <<http://www.dhs.gov/xabout/strategicplan/index.shtm>>.

duties, and protecting against diseases.¹⁵ CBP is also charged with tunnel remediation or the closing of tunnels. The U.S. Border Patrol (USBP) is under CBP and its agents sometimes find tunnels along the borders during everyday patrolling operations. In some Border Patrol Sectors (see Figure 1) that are conducive to tunneling, Border Patrol Tunnel Teams exist to respond to tunnel discoveries.



Figure 1: Border Patrol Sectors as of 2007¹⁶

¹⁵ United States. Cong. House. Testimony. Robert C. Bonner. Washington, D.C: U.S. House, 16 Oct 2003. CBP Archives. Customs and Border Protection (CBP). 29 Nov. 2007 <http://www.cbp.gov/xp/cgov/newsroom/commissioner/speeches_statements/archives/2003/oct162003.xml>.

¹⁶ Rivera, Ramon. U.S. Border Patrol. Email. 26 Oct. 2007.

Department of Homeland Security – DHS

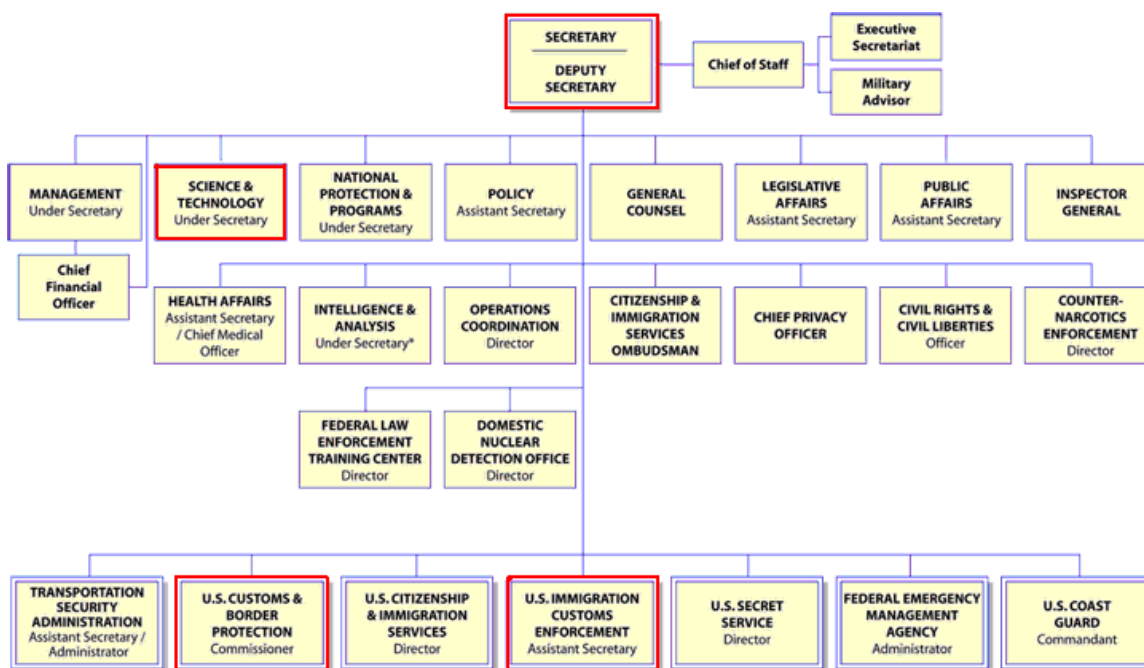


Figure 2: Department of Homeland Security Organizational Chart¹⁷

USBP's primary mission is to detect and prevent the entry of terrorists, WMD, and unauthorized aliens into the U.S. through ports of entry (POE). It also interdicts drug smugglers and other criminals between POE.

Two primary agencies are in charge of investigations after tunnels have been identified: ICE and the Drug Enforcement Agency (DEA). ICE is the agency under DHS (see Figure 2) that investigates immigration crimes, human rights violations, and smuggling of humans, narcotics, and weapons.¹⁸ DEA is a division of the Department of Justice (DOJ) (See Figure 3).

¹⁷ "Organizational Chart." 3 Aug. 2007. Department of Homeland Security. 29 Dec. 2007 <http://www.dhs.gov/xabout/structure/editorial_0644.shtm>.

¹⁸ "About Us." 11 Oct. 2007. U.S. Immigration and Customs Enforcement. 29 Nov. 2007 <<http://www.ice.gov/about/operations.htm>>.

Department of Defense - DoD

Department of Defense

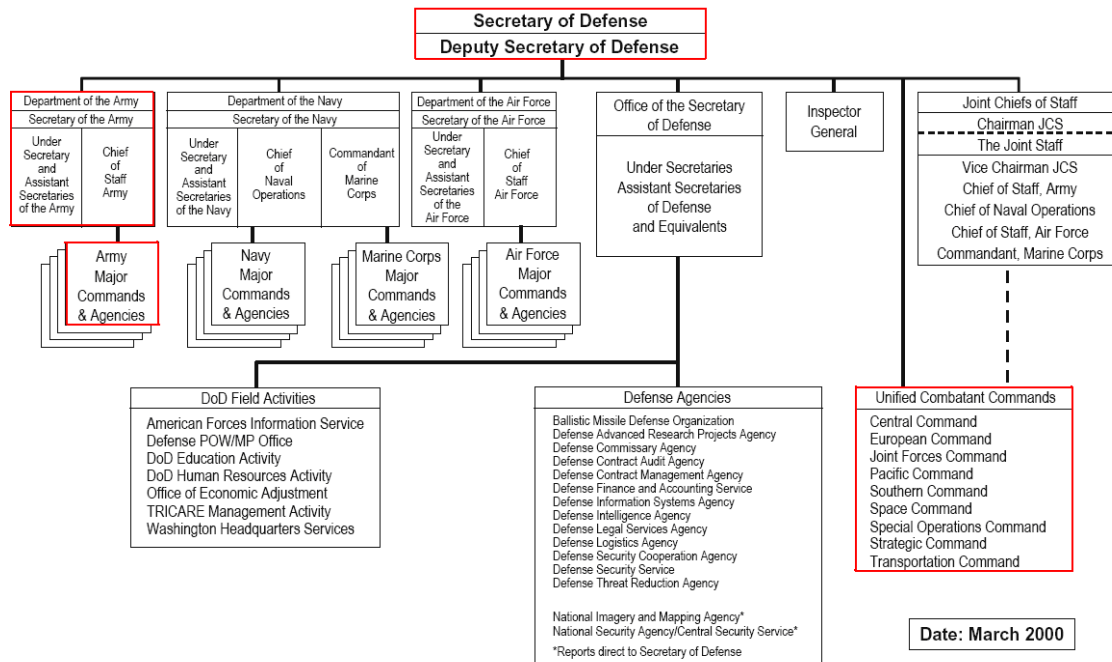


Figure 3: Department of Defense Organizational Chart¹⁹

DoD has three commands with interests in tunnels, both domestically and abroad. U.S. Strategic Command (USSTRATCOM), as discussed in the introduction, is concerned with combating WMD. U.S. Central Command's (USCENTCOM) Area of Responsibility (AOR) includes current areas susceptible to tunneling in Iraq, Afghanistan, Egypt, Israel, and potentially other countries.²⁰ U.S. Northern Command's (USNORTHCOM) mission is to defend, protect, and secure the United States and its interests, including support of counter-drug operations and managing the consequences of terrorist events employing WMD. USNORTHCOM's AOR includes the U.S., Mexico, and Canada, and providing assistance to Lead Agencies when tasked by DoD.

¹⁹ "Department of Defense Organizational Chart." Mar. 2000. Department of Defense. 29 Dec. 2007 <<http://www.defenselink.mil/odam/omp/pubs/GuideBook/Pdf/DoD.PDF>>.

²⁰ "CENTCOM Area of Responsibility." United States Central Command. 29 Nov. 2007 <http://www.centcom.mil/sites/uscentcom2/Misc/centcom_aor.aspx>.

NORTHCOM's futures group has been given the task of leading tunnel technology development.²¹

Under USNORTHCOM is Joint Task Force North (JTF-North), a joint service command that counters international terrorism, drug trafficking, alien smuggling, and WMD. In tunnel detection efforts along the southern border, JTF-North has acted in a support role for Law Enforcement Agencies (LEA)'s, interagency synchronization, and information and intelligence sharing.²²

Other agencies under DoD interested in tunnel detection are the Defense Threat Reduction Agency (DTRA), Space and Naval Warfare Systems Command (SPAWAR), National Geospatial-Intelligence Agency (NGA), Defense Advanced Research Projects Agency (DARPA), and the U.S. Army Corps of Engineers' Engineer Research and Development Center (USACE ERDC).²³ DTRA's primary interest is combating WMD. NGA's mission involves the "exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features" as this relates to the identification of cross-border tunnels.²⁴ ²⁵ DARPA is interested in the research and development of tunnel detection technologies. The ERDC has tested multiple tunnel detection technologies, both overseas and along the U.S. southern border. Tunnel detection technology demonstrations and analysis by various vendors and agencies

²¹ Magnuson, Stew. "Hunters Unearth Smuggling Tunnels." National Defense Jul. 2006. 29 Nov. 2007 <<http://www.nationaldefensemagazine.org/issues/2006/july/HuntersUnearth.htm>>.

²² "Mission." Joint Task Force North. 29 Nov. 2007 <<http://www.jtfn.northcom.mil/subpages/mission.html>>.

²³ JTF-North. "JTF-North Support to Tunnel Detection Operations." PowerPoint presentation. 10 Oct. 2007.

²⁴ "Welcome to DTRA". Defense Threat Reduction Agency. 29 Nov. 2007 <<http://www.dtra.mil/>>.

²⁵ "The National Geospatial-Intelligence Agency (NGA)." National Geospatial-Intelligence Agency. 29 Nov. 2007 <<http://www.nga.mil/portal/site/nga01/index.jsp?epi-content=GENERIC&itemID=31486591e1b3af00VgnVCMSTServer23727a95RCRD&beanID=1629630080&viewID=Article>>.

including ERDC, USNORTHCOM, U.S. Geological Survey, and Sandia National Labs took place at Otay Mesa and Calexico, California, in 2006.²⁶

Department of Justice – DOJ

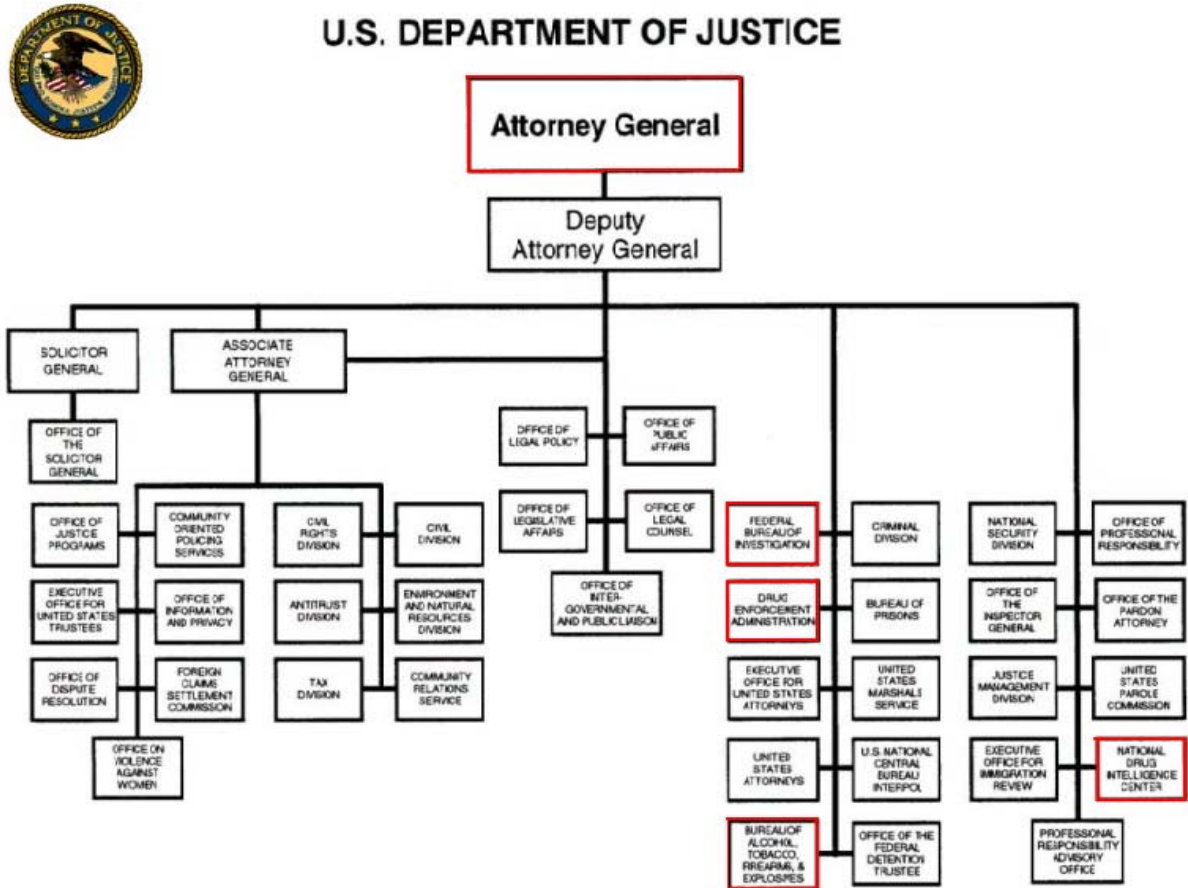


Figure 4: Department of Justice Organizational Chart²⁷

Under DOJ (See Figure 4) is the other agency involved in tunnel investigations for drug trafficking and enforcement, DEA. Under DEA is the El Paso Intelligence Center (EPIC) which is the Southwest border’s “regional intelligence center that collects and disseminates information on drug, alien, and weapon smuggling, in support of field

²⁶ McKenna, Jason R., Robert Horton, Gregory Elbring, Amy Clymer, and Clifford Hansen. “Tunnel Detection Technology Demonstrations: Otay Mesa and Calexico, California.” U.S. Army Corps of Engineers - Engineer Research and Development Center. Dec. 2006.

²⁷ “Department of Justice Organizational Chart.” 13 Mar. 2006. Department of Justice. 29 Dec. 2007 <<http://www.usdoj.gov/dojorg.htm>>.

enforcement entities.”²⁸ Other potential agencies involved with tunnel investigations under DOJ are the Federal Bureau of Investigations (FBI), the U.S. Attorney’s Office, the National Drug Intelligence Center (NDIC), and the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF).²⁹

Other Agencies and Procedures

Other agencies and multi-agency operation centers include the USBP’s Field Intelligence Center (BORFIC) and the High Intensity Drug Trafficking Areas (HIDTA) operatives (See Figure 5). BORFIC screens information on drug, alien, and weapons smuggling and provides daily summaries of intelligence reports in support of the CBP’s Offices of Intelligence and Field Operations, ICE, DOJ’s Organized Crime Drug Enforcement Task Force (OCDETF), HIDTA, Office of National Drug Control Policy (ONDCP), and other agencies.³⁰ HIDTA has four border regions with historical tunneling problems: the California, Arizona, New Mexico, and Washington.



Figure 5: HIDTA Headquarters and Southwest Border Regions³¹

²⁸ “El Paso Intelligence Center.” U.S. Drug Enforcement Administration. 29 Nov. 2007
<<http://www.dea.gov/programs/epic.htm>>.

²⁹ United States. Cong. House. Testimony. Robert C. Bonner. Washington, D.C: U.S. House, 16 Oct 2003. CBP Archives. Customs and Border Protection (CBP). 29 Nov. 2007
<http://www.cbp.gov/xp/cgov/newsroom/commissioner/speeches_statements/archives/2003/oct162003.xml>.

³⁰ United States. Cong. House. Testimony. Robert C. Bonner. Washington, D.C: U.S. House, 16 Oct 2003.

³¹ “High-Intensity Drug Trafficking Areas.” 2 May 2007. Office of National Drug Control Policy. 30 Dec. 2007 <<http://www.whitehousedrugpolicy.gov/HIDTA/>>.

In the U.S., four major steps occur from a tunnel's identification to its closure. First, law enforcement agencies are notified of the suspected identification of a tunnel. Usually because of a human intelligence report. Next, exploitation ensues as a DHS or DOJ organization digs to confirm a tunnel's existence or executes a warrant to locate entrances. DHS will remain the lead agency from the exploitation process until the end. Post-seizure analysis then takes place as justice and intelligence data is recovered; during this process of confirmation, LEAs are supported by JTF-North. Finally, after all the intelligence data has been gathered and environmental permits have been obtained, the tunnel is closed by CBP, with technical advice and sometimes tunnel detection operational assistance from JTF-North.^{32 33}

Political and Geographic Border Characteristics

The U.S.-Mexico border spans 1,969 miles over four U.S. states (California, Arizona, New Mexico, and Texas) and six Mexican states (Baja California, Sonora, Chihuahua, Coahuila de Zaragoza, Nuevo Leon, and Tamaulipas) (See Figure 6). Areas susceptible to tunneling include about 715 miles over land, beginning in urbanized California, through the Arizona and New Mexico desert, and ending with El Paso, Texas.³⁴ The portion of the border between Texas and Mexico is of little interest because of the presence of the Rio Grande River.

The U.S.-Canada border's land boundary spans 4,683 miles over thirteen U.S. states (Alaska, Washington, Idaho, Montana, North Dakota, Minnesota, Michigan, Ohio, Pennsylvania, New York, Vermont, New Hampshire, and Maine) and eight Canadian provinces (Yukon Territory, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, and New Brunswick) (See Figure 7). Its terrain varies in the west from forests in Alaska, to Vancouver Island, urbanized British Columbia, the Coast and Rocky

³² JTF-North. "JTF-North Support to Tunnel Detection Operations." PowerPoint presentation. 10 Oct. 2007.

³³ JTF-North. "Technology." PowerPoint presentation. 4 Sept. 2007.

³⁴ "Mexico – United States Border." 17 Dec. 2007. Wikipedia.com. 28 Dec. 2007
<http://en.wikipedia.org/wiki/United_States%E2%80%93Mexico_border>.

Mountains, grasslands and plains, and finally some areas not susceptible to tunneling, such as the Great Lakes and St. Lawrence River in the east.³⁵



Figure 6: U.S.-Mexico Border Map



Figure 7: U.S.-Canada Border Map

³⁵ "Canada & the United States Border." International Boundary Commission. 12 Dec. 2007
http://www.craigmarlatt.com/canada/canada&the_world/canada&us_border.html.

Political Environment Pre- 9/11

Particularly salient to an examination of the tunnels constructed and discovered both pre- and post-9/11 is an assessment of the social and political conditions that existed on the U.S. borders with Mexico and Canada. These conditions provide a backdrop which can aid in understanding both why tunnels have been constructed under U.S. borders, and also why interest in such tunnels has been a relatively recent development.

U.S. – Mexico Pre-9/11

A desire for free trade significantly opened up border between the U.S. and Mexico during the 1990's. Before 9/11, leaders from both Mexico and Canada were engaging in the possibility of opening the borders even further. Former Mexican President Vicente Fox ran his presidential campaign on the platform of a "borderless world" where labor and goods could flow freely; the result would be the "creation of a North American community." The porous border would be a reflection of globalization and a new age of "harmonious cross-border relations." While the North American community never came to full fruition, policy did move toward both strict border control policy and economic integration during the 1990's. These conflicting actions created "both a borderless economy and a barricaded border" making the border both more blurred and defined.³⁶

Anti-immigration uprisings and the dedication to the "war on drugs" caused a surge in border controls during the early 1990's. The border enforcement build-up has been described by Peter Andreas as "a politically successful policy failure." The policy failed in that it did not deter drugs or people from illegally entering the U.S.; however, the political success came in that the border enforcement was visible and held symbolic value. Because of press coverage, the border appeared to be more secure as unauthorized aliens and drugs were confiscated along the border areas, especially in key areas of concern. The reality was that neither the illegal flow of drugs nor people had been controlled on the border; rather, the traffic was redirected to new areas. Andreas says, "At best, the [pre-9/11] enforcement crackdown affected the methods and specific locations

³⁶ Andreas, Peter. "A Tale of Two Borders: The U.S.-Mexico and U.S.-Canada Lines After 9/11." May 2003. The Center for Comparative Immigration Studies at the University of California - San Diego. 20 Dec. 2007. <<http://www.ccis-ucsd.org/PUBLICATIONS/wrkg77.pdf>>.

of drug trafficking across the border, but without a noticeable reduction in the overall supply.”³⁷

Andreas finds that the new border enforcement policy had three main counterproductive effects. First, alien smuggling organizations (ASO) and drug trafficking organizations (DTO) started to perfect their criminal enterprises. Second, the crackdown caused “closer ties between licit and illicit trade.” For example, DTO used the increase in legally traded goods to camouflage their drug sales in semi trailers that crossed at Ports of Entry (POE). Third, the flow of illegal immigrants and drugs were directed away from POE and toward rural areas because of increased border security and more Border Patrol agents. Thus, the number of migrant deaths increased dramatically as people began to cross in the hot deserts and rugged mountainous areas.³⁸

U.S. – Canada Pre-9/11

The U.S.-Canada border has historically been one of the friendliest and most open boundaries in the world. For Canada, the pre-9/11 era did not bring any dramatic change to political direction. Canada’s confidence in their system soared even as policies began to show weakness. While the increase in commerce due to the North-American Free Trade Agreement (NAFTA) was welcome, the flow of people was alarmingly unchecked. NAFTA, outdated laws, and a terrorist incident in 1999 can be used to illustrate Canada’s security climate pre-9/11 and also, contrast with the major changes that would come after-9/11.

Canada’s lax immigration and refugee laws were an obvious security weakness pre-9/11, although reform was not addressed until much later. In 2001 a Canadian Police Association officer stated,

Our proximity to the United States of America makes Canada extremely vulnerable, however it is our lax immigration policy, open borders, weak laws,

³⁷ Andreas. “A Tale of Two Borders: The U.S.-Mexico and U.S.-Canada Lines After 9/11.”

³⁸ Andreas. “A Tale of Two Borders: The U.S.-Mexico and U.S.-Canada Lines After 9/11.”

archaic justice system, an even weaker corrections system and under enforcement that make us extremely attractive to the sophisticated criminal.³⁹

For immigration, Canada mostly relies on a paper system of identification, one that has not been adjusted in spite of the fact that false documents can be bought on the black market for around \$1,000. Another point of policy makers' discontent with Canada's immigration system is that Canada allows sixty countries "visa-free entry." Moreover, discontent with Canada's refugee asylum policy lies with the definition of refugee: anyone claiming refugee status was granted a hearing, even without documentation. Many such "refugees" never appeared for their hearings. In addition, refugees claiming danger to their lives were often allowed asylum in Canada pending determination of their status. This process could take years, providing a dangerous loophole.⁴⁰

One incident along the U.S. – Canada border did begin to get Law Enforcement Agencies (LEAs) thinking about Canada as a terrorist haven. On December 14, 1999 Ahmed Ressay, later to be known as the "Millennium Bomber," was apprehended in Port Angeles, Washington after a U.S. Border Patrol agent stopped Ressay because of his uneasy composure. Ressay was arrested for smuggling 100 pounds of explosives into the U.S. with the intent to bomb the Los Angeles International Airport. After his arrest, Ressay was identified as a member of the Algerian Armed Islamic group - a group with loose ties to Al-Qaeda.⁴¹

The "world's longest undefended border" was a source of pride for both Canadians and Americans. The continued lack of militarization (and the absence of controversy about it) pre-9/11 demonstrates the symbolic nature of the border as a reflection of the confidence both countries maintained with each other. While the pre – 9/11 U.S.-Canadian border may have been treated dismissively, surely this relationship would be preferred over the negative attention which followed.

³⁹ United States. Library of Congress. *Nations Hospitable to Organized Crime and Terrorism*. Washington, D.C.: Federal Research Division. Oct. 2003.

⁴⁰ United States. Library of Congress. *Asian Criminal and Terrorist Activity in Canada*. Washington, D.C.: Federal Research Division. July 2003.

⁴¹ United States. Library of Congress. *Asian Criminal and Terrorist Activity in Canada*.

NAFTA

In spite of the enhanced border security, the increased truck traffic and bi-national trade induced by the North-American Free Trade Agreement (NAFTA) were immediately visible along U.S. borders. According to the Organization for Economic Cooperation and Development, between 1993 and 2000, trade between the U.S. and Mexico tripled from \$81 billion to \$247 billion per year.⁴²

After the creation of NAFTA, ten new ports were added to the U.S. – Mexico border to facilitate this increased trade. However, “border law enforcement never trumped the facilitation of legitimate border crossings.”⁴³ Both Canada and Mexico send at least eighty-five percent of their exports to the U.S., so the movement of legitimate goods and facilitation of just-in-time inventory is vitally important to all three countries’ economies. The creation of the Free and Secure Trade (FAST) program encouraged authorized trade between the three countries. FAST is a voluntary government-business program that is vitally important to these countries’ economies particularly because 75-80% of the trade between Mexico and the US is transported via trucks.⁴⁴

NAFTA called for the phasing out of virtually all restrictions on trade and investment flows between the U.S., Canada, and Mexico over ten years. Since 1994, though, U.S. and European agricultural subsidies have not declined overall and have thus hindered Mexico’s agricultural sector due to lower world prices.⁴⁵ “In other sectors such as the maquiladora (manufacturing industry), NAFTA-induced growth along the border has taken the form of increased industrial development and associated sectors. Manufactured goods from the maquiladoras account for nearly fifty percent of Mexico’s total exports.”⁴⁶

⁴² Bassett, Leslie. “Bridges, Barriers, or Both? The U.S. Borders.” Foreign Service Journal (Oct. 2007):13-16.

⁴³ Andreas. “A Tale of Two Borders: The U.S.-Mexico and U.S.-Canada Lines After 9/11.”

⁴⁴ “Deciphering the Visa Code.” Sep. 2005. U.S. Department of State’s eJournal USA. 11 Dec. 2007 <<http://usinfo.state.gov/journals/itps/0905/ijpe/visacode.htm>>.

⁴⁵ “Effects of NAFTA on U.S.-Mexican Trade and GDP.” May 2003. Congressional Budget Office. 11 Dec. 2007 <<http://www.cbo.gov/ftpdoc.cfm?index=4247&type=0&sequence=1>>.

⁴⁶ Baptista, May G. “The Great Tijuana Experience.” Foreign Service Journal (Oct. 2007): 26-28.

Agricultural and temporary worker demand in the U.S. is very high. Especially during times of economic growth, labor demand rises. Many workers to meet this demand arrive from Mexico with hopes of earning higher wages than they would earn in their home country. Even after NAFTA was passed, Mexico's increase in working population (1.2 million per year) has outpaced its job creation (400,000 per year) in the regular economy.⁴⁷ Unfortunately, many new jobs were then created in the "underground" economy, which provided higher earnings in trades like drug and human smuggling - both of which occur in cross-border tunnels.

Security Conditions, Pre-9/11

Conditions pre-9/11 allowed an unwarranted confidence in U.S. national security to flourish. While national security has always been a domestic priority; the 9/11 attacks were largely responsible for overturning the complacency of the American public. For a very long time, national security was simply taken for granted. Two important notes should be made about the security conditions that, in fact, existed with the U.S. and neighbors before 9/11: first, immigration policy needed reform, and second, drug control efforts were not succeeding in enhancing security.

First, immigration policy was in need of serious reform as the number of illegal immigrants grew sharply during the 1990's and cheap labor in the U.S. was still in high demand. For instance, cities across the Midwest experienced an influx of Latino immigrants as meat packing plants enjoyed the opportunity to exploit cheap labor. The system had yet to catch up to the number of worker visas that were needed in order to sustain the demand.

Second, drug policy in the U.S. before 9/11 placed a significant focus on a supply-side approach to combating the entry of illegal narcotics. However, it is widely believed that the U.S. War on Drugs has been a failure specifically because of this approach. U.S. demand remains unchanged – the highest in the world – in spite of the illegality of the substances. For a country like Mexico, this approach creates an environment in which the smuggling of narcotics to the U.S. is lucrative because of high payoffs. In spite of U.S.

⁴⁷ Suarez-Mier, Manuel. "A View From the South." Foreign Service Journal (Oct. 2007): 17-22.

attempts at controlling the flow of narcotics from Mexico, corruption on the southern side of this border made efforts token gestures rather than legitimate security.

Border Security Post-9/11

While legislation, new departments, increased funding, new security mechanisms, and increased awareness have allowed the U.S. to celebrate incremental strides in securing the border, the U.S. borders are still permeable and easily infiltrated. Counter-terrorism success will never be highly visible, but if border security deterrence of unauthorized migrants or narcotics is used as an indicator of post-9/11 security improvements, security reform is far from complete. As Andreas says, "If the existing border enforcement apparatus has proven unable to stop multi-ton shipments of drugs and hundreds of thousands of crossings by unauthorized migrants every year, the chances of deterring a few bombs or terrorists is far more remote."⁴⁸

Since 1993, the U.S. government has focused on deterrence approaches to U.S.-Mexico border security, emphasizing increased concentrations of patrol agents along the borders. One scholar noted that despite the unprecedented spending allocated to the effort, the enhanced border enforcement has not deterred "significant numbers of unauthorized migrants from attempting entry," and additionally has caused a large number of migrant deaths, and an increase in migrants' length of stay, some even settle permanently.⁴⁹ Other research indicates that, rather than stopping drug and human smuggling, deterrence methods have simply forced smugglers into creating and using new routes for their activities. A map of the new routes (see Figure 8) indicates that migrants are moving away from the urban areas where the border security forces were concentrated after 9/11.

⁴⁸ Andreas. "A Tale of Two Borders: The U.S.-Mexico and U.S.-Canada Lines After 9/11."

⁴⁹ Cornelius, Wayne A. "Evaluating Enhanced U.S. Border Enforcement." 1 May 2004. Migration Policy Institute. 22 Sep. 2007 <<http://www.migrationinformation.org/Feature/display.cfm?ID=223>>.

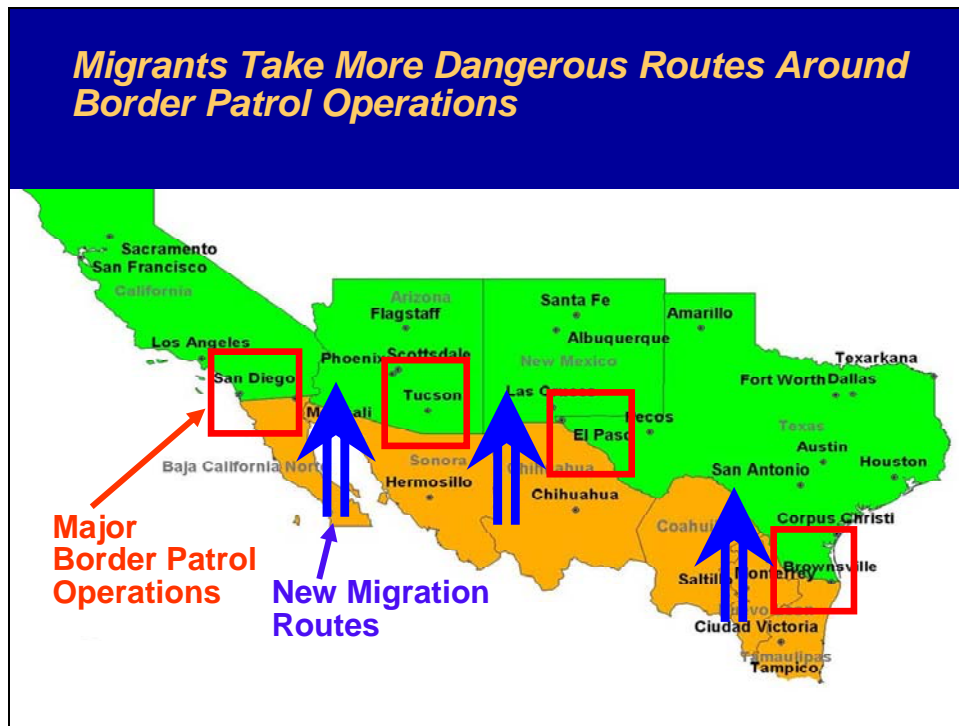


Figure 8: Alternate Migrant Routes⁵⁰

Deterrence of drug and migrant smuggling post-9/11 has proven largely unsuccessful. In spite of this lack of success and a tenuous connection between these activities and the 9/11 terrorist activities, the shift in public concern about border control in the wake of the attacks cannot be denied. A Zogby public opinion survey from a few weeks after the terrorist attacks shows that 72 percent of those polled say better border controls and stricter enforcement of immigration laws would help prevent terrorism. Even with this renewed concern, the public has yet to see results and improvements.⁵¹

Bi-national and Interagency Cooperation for Border Security

Since 9/11, Canada has implemented several initiatives to enhance border security like creating Integrated Border Enforcement Teams (IBET) along the entire U.S.-Canada border. These teams are bi-national, multi-agency law enforcement teams that target border criminal activities, including drug trafficking and terrorism. The teams include members of the Canadian Border Services Agency (CBSA), the Royal Canadian

⁵⁰ Cornelius, Wayne A. "How Border Enforcement has Reshaped Mexican Migration to the United States." Center for Comparative Immigration Studies, University of California-San Diego. Sept. 2007. http://polisci.ucsd.edu/cornelius/papers/SDUT.ppt#1501.1.Slide_1

⁵¹ Andreas. "A Tale of Two Borders: The U.S.-Mexico and U.S.-Canada Lines After 9/11."

Mounted Police (RCMP), and in the U.S., the CBP and Border Patrol, ICE, and the U.S. Coast Guard. The CBSA is similar to the CBP in the U.S. in that it establishes how people and goods move through the border, detains illegal goods, and prevents people from crossing the border who pose a threat or are suspected of terrorism.⁵² The RCMP is the Canadian national police service which provides law enforcement along the border to deter terrorism, organized crime, and drugs.⁵³ The IBET teams have been successful at combating organized crime and threats to national security along all fifteen geographical areas on the northern border. All IBET teams except the team in British Columbia began after 9/11.^{54 55}

An additional bi-national cooperative effort includes⁵⁶ the creation of the Canada-U.S. Cross Border Crime Forum (CBCF) in 1997 to address transnational crime issues; this forum has met eight times since.⁵⁷

On November 1, 2001, Mexico's Attorney General's Office and President Vicente Fox established a new police force called the Federal Agency of Investigation (AFI) which replaced the notoriously corrupt Federal Judicial Police. The AFI is developing into a professional police force focusing on deterring corruption in order to effectively investigate federal crimes. Another Mexican law enforcement group is the Federal

⁵² United States. Congressional Research Service. Border and Transportation Security: Selected Programs and Policies. Lisa M. Seghetti, Jennifer E. Lake, and William H. Robinson. Washington, D.C.: Library of Congress, 2005. 29 Mar. 2005. CRS Web. 12 Dec. 2007 <<http://www.fas.org/sgp/crs/homsec/RL32840.pdf>>.

⁵³ "About the RCMP." 31 Aug. 2007. Royal Canadian Mounted Police. 12 Dec. 2007 <http://www.rcmp.ca/about/index_e.htm>.

⁵⁴ Office of the U.S. Press Secretary. "U.S. - Canada Smart Border/30 Point Action Plan Update." 6 Dec. 2002. The White House. 12 Dec. 2007 <<http://www.whitehouse.gov/news/releases/2002/12/20021206-1.html>>.

⁵⁵ "Canada and the United States Strengthen Partnerships to Tackle Cross-Border Crime." 22 Oct. 2004. Public Safety Canada. 12 Dec. 2007 <http://ww2.ps-sp.gc.ca/publications/news/2004/20041022_e.asp#CBCF>.

⁵⁶ "Canada and the United States Strengthen Partnerships to Tackle Cross-Border Crime." Public Safety Canada.

⁵⁷ "Report of the Government of Canada to the Counter-Terrorism Committee (CTC) of the United National Security Council in Response to the Letter of the Chairman of the Committee." 7 Mar. 2002. Foreign Affairs and International Trade Canada. 12 Dec. 2007 <http://www.dfait-maeci.gc.ca/trade/resolution_1373_june7-en.asp>.

Preventive Police (PFP) which was created in 1999 by President Ernesto Zedillo. Its mission is to prevent and combat crime throughout the country. Its structure has effectively merged major law enforcement officials from migration, treasury, and transportation agencies.⁵⁸ Grupo Beta is a Mexican law enforcement agency that operates along the border; this agency is a “government-sponsored group that tries to discourage migrants from crossing and aids those stranded in the desert.”⁵⁹ USBP officials frequently work with these Mexican agents on cross-border crimes, including those occurring in tunnels.

Binational cooperation is also important for legitimate commercial travel. Continued facilitation of these activities is necessary since about one million Americans reside in Mexico and twelve million more visit every year. In recent years, additional programs have been implemented between the three countries to facilitate legitimate travel and commerce, including NEXUS, the Secure Electronic Network for Travelers Rapid Inspection (SENTRI), and Border Crossing Cards (BCCs).⁶⁰ NEXUS is a program between Canada and Mexico to simplify land, air, and sea border crossings for pre-approved, low-risk travelers between the two nations.⁶¹ SENTRI reduces the wait time for frequent travelers between Mexico and the United States. Since this international border is the busiest in the world, dedicated commuter lanes were created in 1995 to ease traffic wait times. BCCs also exist for travelers crossing the US-Mexican border. These contain biometric identifiers and serve as business/tourist visas for ten years.⁶² These programs have been effective at facilitating legitimate trade and travel between the three countries.

⁵⁸ Reames, Benjamin. “Police Forces in Mexico: A Profile.” USMEX 2003-04 Working Paper Series. 2007. Center for U.S. Mexican Studies. 12 Dec. 2007
<<http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1025&context=usmex>>.

⁵⁹ “Illegal Entry From Mexico to U.S. Spikes.” 27 Apr. 2004. NewsMax.com. 12 Dec. 2007
<<http://archive.newsmax.com/archives/articles/2004/4/27/154444.shtml>>.

⁶⁰ Bassett, Leslie. “Bridges, Barriers, or Both? The U.S. Borders.” *Foreign Service Journal* (Oct. 2007): 13-16.

⁶¹ “NEXUS Program Description.” 10 Dec. 2007. U.S. Customs and Border Protection. 11 Dec. 2007
<http://www.cbp.gov/xp/cgov/travel/trusted_traveler/nexus_prog/nexus.xml>.

⁶² “Deciphering the Visa Code.” Sep. 2005. U.S. Department of State’s eJournal USA. 11 Dec. 2007
<<http://usinfo.state.gov/journals/itps/0905/ijpe/visacode.htm>>.

Secure Border Initiative (SBI)

The SBI began after Congress passed legislation to further secure and protect the U.S. borders by integrating “increased staffing, interior enforcement, greater investment in detection technology and infrastructure, and enhanced coordination on international, Federal, State, and local levels.”⁶³ On September 21, 2006 DHS awarded a contract to Boeing to implement SBInet along the U.S. northern and southwestern borders. SBInet is a program focused on transforming border control through technology and infrastructure and is a part of SBI.⁶⁴ It is focused on deterring, identifying, and classifying above-surface threats and provides tools so agents can efficiently respond to a suspicious event. The initial task order covers twenty-eight miles of border within the Tucson Border Patrol sector with a deployment timeline of eight months.⁶⁵ Mobile sensor towers with cameras, radars, wireless data access points, communications and computer equipment, and a tower security system are being installed to work with a common real-time Common Operating Picture of the border environment.

In Canada, a sensor redeployment plan has been developed to move analog sensors from the southern border to the northern border and replace them with digital sensors. Border Security Evaluation Teams (BSETs) have been implemented throughout the eight northern Border Patrol sectors to establish baseline surveys in remote areas that were not previously monitored.⁶⁶ These ground sensors have been key in detecting cross-border intruders but have not been used for tunnel detection.

⁶³ McCaul, Michael T. House Committee on Homeland Security. A Line in the Sand: Confronting the Threat at the Southwest Border. 27 Aug. 2007 <<http://www.house.gov/mccaul/pdf/Investigaions-Border-Report.pdf>>.

⁶⁴ McCaul, Michael T. House Committee on Homeland Security. A Line in the Sand: Confronting the Threat at the Southwest Border.

⁶⁵ “SBInet: Securing U.S. Borders Fact Sheet.” Sep. 2006. U.S. Customs and Border Protection. 11 Dec. 2007 <<http://www.dhs.gov/xlibrary/assets/sbinetfactsheet.pdf>>.

⁶⁶ “SBInet Timeline.” 13 July 2007. U.S. Customs and Border Protection. 11 Dec. 2007 <http://www.cbp.gov/xp/cgov/border_security/sbi/sbinet_information/sbinet_project_timeline.xml>.

Tunnels on United States Borders to December 2007

Clandestine tunnels that are constructed along the U.S. - Canada and U.S. - Mexico borders are a threat to the U.S. national security. Since the discovery of the first border tunnel in 1990, seventy-one clandestine tunnels have been discovered along the U.S. borders (as of December 31, 2007).⁶⁷ These tunnels are constructed to illegally transport drugs, and to a lesser extent, humans from one country to the other.⁶⁸ These clandestine tunnels have been located in three states and more specifically eight cities including:

Calexico, CA	4
Douglas, AZ	1
Lynden, WA	1
Naco, AZ	1
Nogales, AZ	34
San Diego, CA	26
San Luis, AZ	1
Tierra Del Sol, CA	3

Table 1: Locations of Discovered Clandestine Tunnels

Because this national security matter was not taken more seriously from the beginning – CBP was not actively concerning itself with tunnel detection until after 9/11 – only after the fact can we estimate the length of time that tunneling has been a preferred option. Whether the construction of tunnels began primarily after 9/11 or rather the tunnels were built before and discovered after 9/11 is unknown. Why did the U.S. government not pursue more resources towards tunnel detection pre-9/11? Arguably, the confidence that existed in national security measures allowed tunnels to remain a low-level threat.

⁶⁷ See Appendix A

⁶⁸ United States. Department of Homeland Security. Border Security Branch. Special Assessment. Underground Tunnels: A Border Security Threat. 31 July 2007.

Conversely, many speculate that increased security along the U.S. border post-9/11 has forced illegal activity underground as almost half of all the discovered tunnels, 32, have been discovered within the last two years.⁶⁹

Between 1990 and 2001 the CBP had uncovered thirteen underground tunnels between the U.S. and Mexico. Since 2001, fifty-eight clandestine tunnels have been located along the U.S. border with Mexico, while only one tunnel has been located on the U.S. border with Canada.⁷⁰ While little is known about when construction of tunnels became more frequent, questions surrounding who, where, why, and how have been explored by law enforcement. DHS reports that drug cartels and human smugglers have constructed tunnels to traffic narcotics, illegal migrants, and special interest aliens (SIA) into the U.S.⁷¹ In addition, JTF-North reports that tunnels are used to illegally move money and weapons; however, this traffic is directed out from, rather than into, the U.S.⁷²

As described by a San Diego Tunnel Task Force ICE agent, drug tunnels are visibly different from human smuggling tunnels. Tunnels used to transport drugs tend to be advanced and improved while those used for human smuggling are shallow, small, and unimproved, allowing for just one person to squeeze through. While human smuggling profits are notably on the rise, the profits do not compare to the capital that drug cartels are realizing.^{73 74}

The Seventy-One Tunnels

In February 2005 DHS issued a statement describing a need for information on measures taken to bypass border security measures. Concerning tunnels, DHS posed a series of unanswered questions including:

⁶⁹ See Appendix A

⁷⁰ See Appendix A

⁷¹ United States. Department of Homeland Security. Special Assessment. Underground Tunnels: A Border Security Threat.

⁷² Alfaro, Eric, et al. Border Patrol Field Intelligence Center, Joint Task Force North, San Diego Tunnel Task Force and USNORTHCOM. Telephone conference. 8 November 2007.

⁷³ Smith, Shan. Bureau of Immigration and Customs Enforcement. Personal Interview. 29 October 2007.

⁷⁴ United States. Department of Homeland Security. Special Assessment. Underground Tunnels: A Border Security Threat.

- What are the specific crossing points?
- What is the tunnel's point of origin? What is the tunnel's termination point?
- Who is using the tunnel?
- Who built the tunnel?
- When was the tunnel built?
- What is the tunnel's purpose (drugs, smuggling, illegal immigration, etc.)?
- What are the dimensions of the tunnels?⁷⁵

For existing tunnels, these questions create a clear pattern of activity. The crossing points for tunnels have been found in eight urban areas in Arizona, California, and Washington. The entry and exit points range from underneath a warehouse (most are located under existing infrastructure) to a few feet in front of a border fence. Particularly in Nogales, AZ, bi-national drainage systems are used as an entry and exit point. Again, tunnels are mainly funded by DTOs, but also ASOs.⁷⁶

Drug Tunnels

Since 1990, 31 tunnels have been directly linked to drug trafficking through investigation and confiscation.⁷⁷ For drug cartels, the cost of tunneling is quickly recovered by successful drug shipments. Drugs confiscated from tunnels are typically marijuana and cocaine, although it is widely known that Mexican drug cartels also traffic large amounts of black tar heroin and methamphetamine along with myriad other drugs. To date, neither heroin nor methamphetamine have been confiscated in tunnel detection investigations.⁷⁸

Several tunnels have been linked to specific cartels. In particular, one tunnel has been linked to the Arellano-Felix cartel (better known as the Tijuana cartel) and five tunnels

⁷⁵ United States. Department of Homeland Security. Office of Information Analysis. Standing Information Needs. 14 Feb. 2005.

⁷⁶ United States. Department of Homeland Security. Special Assessment. Underground Tunnels: A Border Security Threat.

⁷⁷ See Appendix A

⁷⁸ United States. Department of Homeland Security. Office of the Americas North America and Homeland Security Division. United States Cross Border Illegal Tunnels. July 2007.

have been linked to Joaquin “el Chapo” Guzman’s Sinaloa cartel. The Arellano-Felix cartel has been connected to a tunnel discovered in Otay Mesa on December 10, 2002. An FBI source linked the Arellano-Felix cartel to an ASO which trafficked Chinese and Middle Eastern aliens into the U.S. The ASO had paid the cartel a “protection tax” to use a tunnel to traffic the aliens from Mexicali to Calexico, hinting to further involvement in the use of tunnels. Guzman’s Sinaloa cartel has been connected to six different tunnels in Calexico, Douglas, Nogales, and Otay Mesa. DHS noted in the 2007 BAA that the Sinaloa cartel believed that tunnels should not be used to traffic unauthorized aliens; moreover, if a tunnel was built to transport drugs, then it should only be used as a drug tunnel.⁷⁹

In Canada the tunnel problem seems most likely to affect the northwest corner of the land border in the westernmost part of the Washington-British Columbia border. On July 20, 2005, U.S. and Canadian LEAs ended the drug trafficking occurring in a tunnel connecting Lynden, Washington, and Aldergrove, British Columbia. While only one tunnel has emerged to date, the area is known for liberal lifestyles and narcotics trade which could foster the need for future tunnel construction.⁸⁰ In nearby Vancouver, nearly 70 percent of criminal activity is associated with illegal drugs. Border agents intercept large amounts of illegal drugs trying to enter the U.S.; in 1999, they seized illicit drugs with a street value estimated at \$351 million.

Human Smuggling

The human smuggling business has increased dramatically in the 21st century. At this point, human smuggling through tunnels has only been an issue with Mexico. In the post-9/11 era of increased border security and the national debate on immigration, there has been an increase in the number of aliens needing the assistance of an ASO to successfully cross the border. While no single ASO has been identified for tunneling to transport

⁷⁹ United States. Department of Homeland Security. United States Cross Border Illegal Tunnels.

⁸⁰ United States. Department of Homeland Security. United States Cross Border Illegal Tunnels.

aliens, investigations have pointed to three tunnels which were used specifically to move humans.⁸¹

Tunnel Types

To effectively search for clandestine tunnels, it is important to identify and classify tunnels based on construction, use, and capabilities. This classification of tunnels will be the initial step in creating an efficient and effective tunnel detection system. Since all technologies to be reviewed operate optimally under specific conditions, it is in the operator's interest to identify which type(s) of tunnels can be detected using a certain technology. For this report, the authors will use three tunnel classification types: unimproved tunnels, improved tunnels, and tunnels which connect to drainage or sewer systems.

Unimproved Tunnels

Unimproved tunnels (See Figure 9) can be as little as a hole in the ground. These tunnels are not intended for long-term use, as indicated by the rushed construction. The absence of shoring materials in these tunnels can lead to the collapse of the tunnel, especially when a vehicle passes by overhead and there have been several documented cases of tunnels found due to collapse as a patrol vehicle drove over them. The other supporting materials are not absolutely necessary, but the exclusion of them can create a dangerous environment inside the tunnel. While lack of a lighting system or drainage system can be viewed as a simple inconvenience, lack of a ventilation system is a much larger concern. Depending on the length of the tunnel, oxygen levels can become dangerously low, endangering the lives of the individuals using the tunnel as well as the Border Patrol agents or other agents who have to investigate the tunnel upon discovery.

⁸¹ See Appendix A



Figure 9: An Unimproved Tunnel^{82 83}

Improved Tunnels

A total of 27 of the 71 tunnels discovered to date have been improved. Improved tunnels (See Figure 10) are defined as tunnels that are constructed with the use of supporting materials. Supporting materials typically used in improved tunnels include (but are not limited to):

- Structural shoring
- Hard-surface floors
- Lighting equipment
- Ventilation systems
- Drainage equipment

⁸² “A Terrorist’s Ticket to the U.S.?” 2007. Abcnews.com. 4 Sept. 2007.
<<http://www.abcnews.go.com/Blotter/popup?id=3456824&contentIndex=1&page=4>>.

⁸³ United States. Department of Homeland Security. Office of the Americas North America and Homeland Security Division. United States Cross Border Illegal Tunnels.



Figure 10: An Improved Tunnel^{84 85}

The use of these materials may range from partial inclusion to total integration into the tunnel. The most common supporting material used is structural shoring, as refined tunnels are most often intended for long-term usage. These tunnels are so technologically advanced that it is possible for them to sustain life for an extended period of time, if needed. Due to the cost involved in the construction of a refined tunnel, it can be concluded that most, if not all, improved tunnels are the work of drug cartels or human smuggling operations.

While structural shoring is the most common supporting material for improved tunnels, most include at least one other. Due to the fact that improved tunnels tend to be longer than most unimproved tunnels, ventilation systems are required to maintain appropriate oxygen levels for the people constructing and using the tunnels. Lighting systems are often used, although most of the installed systems are somewhat primitive as compared to current indoor lighting systems. In several of the improved tunnels discovered, hard-surface floors have been installed to aid in the transportation of materials through the tunnel, indicating a large amount of traffic. Finally, improved tunnels often include

⁸⁴ “A Terrorist’s Ticket to the U.S.?” 2007. Abcnews.com. 4 Sept. 2007.
<<http://www.abcnews.go.com/Blotter/popup?id=3456824&contentIndex=1&page=2>>.

⁸⁵ “A Terrorist’s Ticket to the U.S.?” 2007. Abcnews.com. 4 Sept. 2007.
<<http://www.abcnews.go.com/Blotter/popup?id=3456824&contentIndex=1&page=2>>.

drainage systems. Drainage systems are required when the tunnels extend below the water table. At that depth, water continuously seeps into the tunnel, requiring those using the tunnel to install pumps to remove the water.

Tunnels Connecting to Bi-National Drainage Systems

In addition to unimproved and improved tunnels, a third type of tunneling was found to be prevalent during the research of this topic: drainage system access tunnels (See Figure 11). In areas along the United States' southern border that are prone to flooding, cross-border drainage systems exist below several urban areas. The most significant system is located underneath Nogales, AZ. To date, more than 70% of the tunnels discovered in Nogales have been connected to one of the drainage systems in the city.⁸⁶ The tunneling activity associated with these drainage systems typically involves the use of an unimproved tunnel to gain access to the drainage system(s) on the southern side of the border. Tunnelers then use the drainage system to travel across the border illegally. After crossing the border, the travelers have access to the entire American city through the drains. In most cases, the drainage systems are extremely complex, making effective monitoring difficult.



Figure 11: Nogales Drainage System with Tunnel Connecting⁸⁷

⁸⁶ See Appendix B.

⁸⁷ "A Terrorist's Ticket to the U.S.?" 2007. Abcnews.com. 4 Sept. 2007.
<<http://www.abcnews.go.com/Blotter/popup?id=3456824&contentIndex=1&page=3>>.

Due to legal constraints, it is impossible for the U.S. Border Patrol to actively search for the tunnels used to connect to the drainage systems on the southern side of the U.S.-Mexico border (See Figure 12). Therefore, previously discussed tunnel detection technologies will not be viable for this purpose. To effectively combat the use of the drainage tunnel systems, a methodology based on monitoring and observation, rather than detection, must be considered. The details of this requirement will be discussed in a later section.

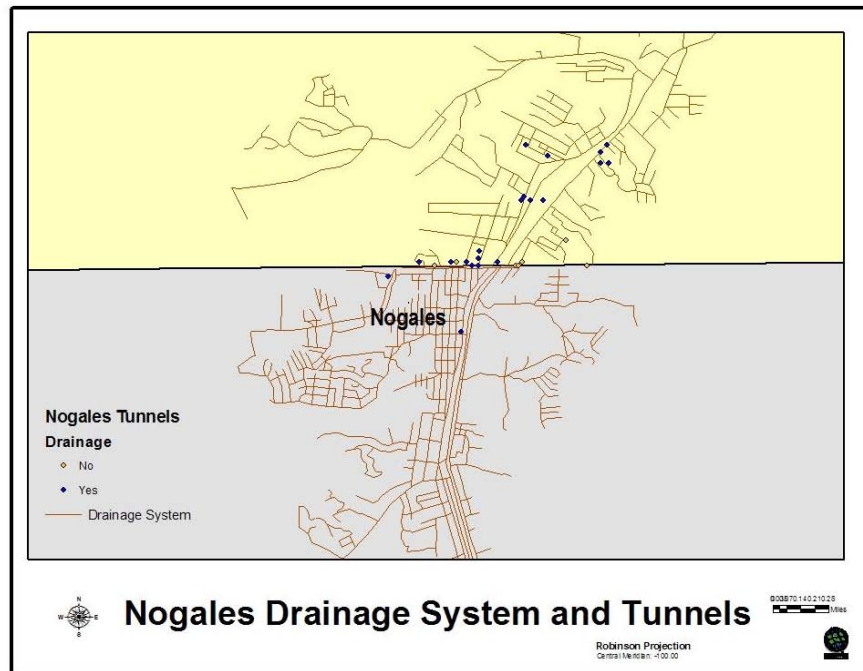


Figure 12: Nogales Drainage System

Construction Methods & Costs

Although there is a distinct difference between unimproved and improved tunnels, the construction methods for each are very similar. While sophisticated digging and boring equipment is sometimes used in the construction of improved tunnels, just as often the same primitive tools and methods are employed as in unimproved tunnel construction.

The cost to construct a clandestine tunnel varies greatly from one case to the next. The cost of each tunnel is directly related to the length and depth of the tunnel. Unimproved

tunnels generally share similar low construction costs, while improved tunnel construction is a costlier venture.

Unimproved tunnels are constructed hastily using hand tools such as shovels and a picks. The resulting tunnel is small, crude, and confining. This uncoordinated construction method is relatively quick and uncomplicated. The cost of digging an unimproved tunnel is not easily estimated due to the small amount of manpower and capital required for construction.

Improved tunnels employ more sophisticated tools. Evidence of the use of jackhammers and other pneumatic excavation tools has been found inside the tunnels. These methods result in larger, more sophisticated tunnels. Due to the increased size and length of improved tunnels, there is a larger amount of soil that must be removed during construction. This soil is carried out of the tunnel in wheelbarrows or carts, and loaded into trucks to be taken away from the site. As tunnels are dug, shoring materials are installed, and ventilation systems are installed. Lighting systems and drainage systems are also installed as required. A concrete floor is sometimes installed after the completion of the digging process.

For improved tunnels, the estimated cost of such structures has ranged from several hundred thousand dollars to upwards of one million dollars. However, these are most likely conservative estimates, as these tunnels are not dug by professional construction crews, but by individuals working for the drug cartels and human traffickers or by civilians forced to dig. These individuals are most likely not paid as well as legitimate construction workers. It is estimated that the income taken in from just one night's operations of a drug cartel is more than sufficient to equal the cost of building the tunnel. However, the information for the construction costs and methods of these tunnels is purely speculative, since there are no reports on first-hand experience with clandestine tunnel detection.

Geological Constraints

Clearly, there are locations which better lend themselves to tunneling based on geological conditions. A few geological considerations which affect tunneling include soil type, depth to the water table, and ground cover. Understanding these conditions can assist

with the decision of what type of technologies to employ in areas along the border as well as to limit the amount of area which needs to be scanned at all.

When analyzing soil type, the main consideration is how collapsible the soil is when tunneled through. Soils with high moisture such as clay, (such as in California), do not cave in as easily, making them more suitable for tunneling. In contrast, loose, sandy soils must be shored to prevent collapsing, thus highly increasing the difficulty and cost of tunneling.

Depth to the water table is another major geological factor which affects the possibility of tunneling. In fact, the water table provides good constraint estimation for the maximum depth of most tunnels, due to the complications it lends when tunneling underneath. Only one known tunnel has breached the water table at a local depth of 90 feet below the Earth's surface; it is unlikely that any organization would try to tunnel much deeper than this example. Depth to the water table varies between locations and ground water in some areas makes tunneling nearly impossible. For example, tunneling along the southern border near the Rio Grande is nearly impossible due to the difficulty level of tunneling under a large river. Figure 13 illustrates the depth to water table near various border cities of interest.

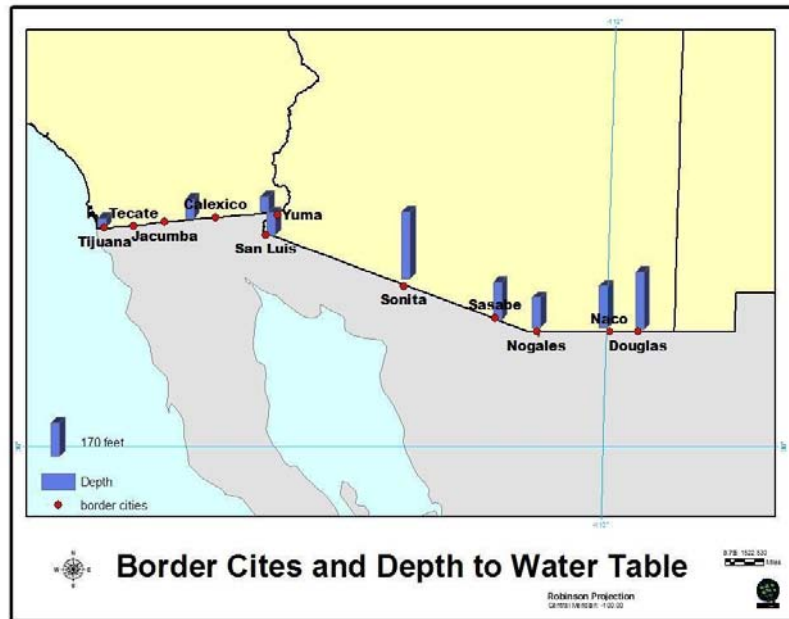


Figure 13: Depth to Water Table, U.S.-Mexico Border Cities^{88 89}

Ground cover also can deter or promote tunneling. A prime example of this includes the rural areas along the border, which can be defined as a lower risk of tunneling. It is more difficult to hide movement of supplies and dirt when large buildings or roads cannot hide entry and exit points. However, these areas should still be considered for tunnel detection, especially if most tunnels are detected in urban areas since tunneling operations will most likely move to more remote areas. All of these geological constraints have had a major impact on where tunneling has occurred and will continue to occur as long as tunneling is still a concern.

The Unknown: Future Tunnels

JTF-North made four definitive statements regarding tunnels in a 2007 presentation. First, they believe there are a number of undetected tunnels along our borders. Second, the tunneling option is being used because of the low costs and high payoffs. Third, the tunnels are the product of an “extensive information network” and the traffickers are

⁸⁸ “ADWR Index Well Sites”. 2007. Arizona Department of Water Resources. 15 Nov. 2007. <<http://arcims.azwater.gov/website/IndexWell/viewer.htm>>.

⁸⁹ “USGS Water Resources.” 2007. United States Geological Survey. 15 Nov 2007. <<http://waterdata.usgs.gov/nwis/current/?type=gw>>.

using private property for tunnel construction. Finally, JTF-North believes that a tunnel could be an entry point for trinitrofluorene (TNT), a chemical used to make bombs.⁹⁰

In assessing the future threat of tunneling to the U.S., DHS summarized its outlook in the 2007 Special Assessment:

- Tunnels will continue to threaten U.S. security, particularly along the southwest border, but tunnels along the U.S. - Canada border will “likely remain rare”;
- tunnel detection will be a dangerous task for U.S. LEAs as the perpetrators are typically major drug cartels that have a history of corrupting Mexican government officials;
- “Densely populated residential areas and growing commercial development” in border cities, “provide smugglers increased opportunities to construct tunnels and exploit the short distances between structures straddling the border.” Smugglers will continue to use “licit businesses, homes, and warehouses to conceal” tunneling;
- Increased Border Patrol operations will cause DTO to find new areas to tunnel;
- DTOs have continued to construct clandestine tunnels regardless of LEAs recent increase in tunnel discoveries.⁹¹

DHS also noted that there are many unknowns surrounding tunneling. The Special Assessment noted that DHS would like to improve its intelligence specifically on the DTO and the ASO which are involved in tunnel operations. A better understanding of the organizations associated with tunneling, including the “tactics, techniques, and procedures” these organizations use could also help LEAs with future detection efforts. Finally, DHS would like to determine if any terrorist organizations have cooperated with DTOs or ASOs in order to penetrate the U.S. border through a tunnel. While no existing

⁹⁰ JTF-North. “JTF-North Support to Tunnel Detection Operations.” PowerPoint presentation. 10 Oct. 2007.

⁹¹ United States. Department of Homeland Security. Special Assessment. Underground Tunnels: A Border Security Threat.

tunnel has been connected to terrorist activity, future utilization of tunneling as an option to terrorists is a primary security concern.⁹²

Illegal Activities

Globalization has allowed for commerce to increase, ideas to flow, and people to become more interconnected by far reaching means. Yet, globalization has no filter and the movement of unwelcome people and unwanted material is an inevitable byproduct. The Director of National Intelligence, John Negroponte, stated in the 2007 Annual Threat Assessment, “The challenge we face is not catching up to globalization or getting ahead of globalization – it is recognizing the degree to which our national security is inextricably woven into the fabric of globalization.”⁹³ Money laundering, human trafficking, drug trafficking, small arms trafficking, human smuggling, racketeering, illegal gambling, and identity theft are some of the criminal enterprises that clandestine non-state actors exploit for profit. Criminal organizations might only specialize in one illegal activity; however, because criminal entities tend to exercise the same resources (i.e. obtain false documents to illegally travel) it is time that these groups cooperate at least with a low level of respect and understanding.

As stated earlier, in addition to drug and human smuggling, money laundering and weapons smuggling also occurs through tunnels. No known figures are available on the amount of money that is laundered or the amount of weapons that are smuggled through tunnels.

Another activity that may be subtly connected to tunneling is the use of false documents. False documentation has been used to get into Canada and Mexico and aliens also smuggle themselves into the U.S.⁹⁴ Since this method has been documented as people smuggle themselves across by foot, it could be used by someone who wanted to smuggle themselves via water or clandestine underground tunnels. Similarly, trafficking

⁹² United States. Department of Homeland Security. Special Assessment. Underground Tunnels: A Border Security Threat.

⁹³ United States. National Intelligence Agency. Annual Threat Assessment and U.S. National Security Challenges. Washington, D.C.: Department of State. 11 Jan. 2007.

⁹⁴ United States. Library of Congress. Nations Hospitable to Organized Crime and Terrorism.

organizations in both Mexico and Canada have established routes to move human beings for labor or sexual exploitation. Both Canada and Colombia are included as Tier 1 (worst offenders) in the 2006 Trafficking in Persons report.⁹⁵ Canada is a major destination for traffickers trying to illegally move people into the U.S.⁹⁶ Again, it is not hard to imagine that these criminal enterprises may one day begin utilizing a clandestine tunnel route.

Terrorism

The Special Assessment report issued by DHS in 2007 clearly hints to the LEAs principal concern on tunnels: terrorism.⁹⁷ If increased security has caused drug and human smuggling to go underground, will terrorists follow the trend, too? Even though the existing tunnels have not been connected to any terrorist activity, LEAs without a doubt are considering the possibility a reality. Then again, a recent news story spoke about an Iraqi terrorist threat on Fort Huachuca, AZ. The report says the FBI is following up on the terrorist threat and that it is suspected that the Iraqis entered the U.S. through a tunnel crossing from Mexico into Arizona.⁹⁸ Even though the FBI later recanted the possible threat, this situation illustrates the vulnerabilities to national security created by clandestine tunnels.

There has been no solid indication of a terrorist organization establishing a presence in Mexico. Immediately following 9/11, comments were made by a former Mexican national security adviser and current ambassador to the United Nations (UN), Adolfo Aguilar Zinser which stated,

Spanish and Islamic terrorist groups are using Mexico as a refuge... In light of this situation, there are continuing investigations aimed at dismantling these groups so that they may not cause problems in the country. We have cases of

⁹⁵ United States. Office to Monitor and Combat Trafficking in Persons. 2007 Trafficking in Persons Report. Washington, D.C.: Department of State. Jun. 2007.

⁹⁶ United States. Library of Congress. Nations Hospitable to Organized Crime and Terrorism.

⁹⁷ United States. Department of Homeland Security. Special Assessment. Underground Tunnels: A Border Security Threat.

⁹⁸ Mackey, Aaron. "FBI: Widely Reported Terrorist Threat to Fort Huachuca Unfounded." Arizona Daily Star 26 November 2007. 28 December 2007 <http://www.azstarnet.com/sn/hourlyupdate/213456.php>.

many terrorist organizations that are seeking to set up refuges in Mexico. They are Islamic people.⁹⁹

Zinsar mentioned that these operations were located in the north, but were shifting south. Most observers believed that Zinsar was hinting at the presence of Hezbollah “because of the sizable ethnic Lebanese and Palestinian communities” in Monterrey, Mexico.¹⁰⁰

After 9/11, concerns focused on the possible presence of Al-Qaeda cells in Mexico. In October 2001 the director of Mexico’s Center for Intelligence and National Security, Eduardo Medina Mora, stated “the possibility of an Al-Qaeda attack against the U.S. launched from Mexico could not be ruled out.” However, Mora also noted he had no reason to believe that Al-Qaeda had a current presence in Mexico. Another official of the National Migration Institute, Felipe Urbiola Ledezma, made a statement noting the institute’s observation of “unusual immigration flows” hinting to the presence of cells from the “ETA, Hezbollah and even some with links to Osama Bin Laden.” Shortly thereafter, the National Migration Institute renounced Ledezma statements and denied any knowledge of terrorist activity in Mexico.¹⁰¹

Even without any solid recognition of terrorist operations in Mexico, officials from both the U.S. and Mexico recognize the possibility exists. A Library of Congress (LOC) report summarizes a variety of reasons why Mexico functions as a desirable safe haven for terrorists and transnational criminal syndicates:

Conditions include geographic proximity and ease of access to the United States; the presence of extra-regional immigrant communities; the volume and sophistication of domestic commercial activity; the volume and ease of trans-border movements of goods, persons and cash; the presence of an established criminal infrastructure; the regulatory environment, transparency, and

⁹⁹ United States. Library of Congress. Organized Crime and Terrorist Activity in Mexico, 1999-2002. Washington, D.C.: Federal Research Division. February 2003.

¹⁰⁰ United States. Library of Congress. Organized Crime and Terrorist Activity in Mexico, 1999-2002.

¹⁰¹ United States. Library of Congress. Organized Crime and Terrorist Activity in Mexico, 1999-2002.

corruptibility of Mexican institutions; and the capabilities of local law enforcement agencies.¹⁰²

A Library of Congress (LOC) report found that criminal groups exploit the corrupt Mexican legal system and also, use corruption on the American side of the border to assist with the uninterrupted movement of illegal goods and people. On a final note, the LOC report forewarns this corruption also attracts non-Mexican criminal enterprises.¹⁰³

It is widely known that the Canadian border could be easily infiltrated by a terrorist. In September 2007 congressional investigators released a report warning that, “A terrorist wanting to smuggle radioactive material from Canada into the United States probably would find it easy to do.” In order to prove this point, the investigators videotaped a man crossing the U.S. – Canada border three times with fake radioactive material. Needless to say, the perpetrator crossed unscathed and unquestioned.¹⁰⁴

Moreover, Canada’s geographic proximity and characteristics and lax asylum and immigration laws to the U.S. make the country an ideal transit point for terrorists or transnational criminal organizations. The LOC report finds that in 2000 Canada was home to over 50 terrorists’ organizations most notably including the Algerian Armed Islamic Group, Egyptian Islamic Jihad, Tamil Tigers, Sikh extremists, Kurdistan Worker Party, and Hezbollah. The report also finds that because of the length of the border it is more realistic to stop terrorists and transnational criminal syndicates from entering the Canada rather than trying to stop their movement once they have arrived.¹⁰⁵

Tunnel Detection Efforts

To date tunnel detection has been limited to the assistance police receive from the public regarding illegal matters. No tunnel detection technology has been used as a first indicator of a tunnel’s existence.

¹⁰² United States. Library of Congress. Nations Hospitable to Organized Crime and Terrorism.

¹⁰³ United States. Library of Congress. Nations Hospitable to Organized Crime and Terrorism.

¹⁰⁴ Bohn, Kevin. “Report: Security on U.S.-Canada Border Fails Security Test.” Cable News Network (CNN) 28 Sept. 2007. 28 Dec, 2007 <<http://www.cnn.com/2007/US/09/27/border.security/index.html>>.

¹⁰⁵ United States. Library of Congress. Nations Hospitable to Organized Crime and Terrorism.

A number of tunnel investigations have exposed corrupt Mexican officials and their involvement in securing tunnel operations. Involvement can range from looking the opposite direction while people and goods enter a tunnel or actually digging portions of a tunnel. One Mexican official was accused of assisting narcotics traffickers, “by providing visual surveillance, monitoring DHS/Customs and Border Protection positions, and instructing couriers when to load the drugs into waiting vehicles on the U.S. side.”¹⁰⁶

U.S. Public Information Efforts

Since all illegal tunnels have been built and used directly under the U.S. borders with Mexico and Canada, residents in these areas should be aware of actions to take if one suspects illegal activities, or specifically, if tunnel construction is taking place near their places of work or residency.

At a minimum, in the Royal Canadian Mounted Police’s British Columbia sector, law enforcement officials currently conduct door-to-door public information campaigns to inform border residents of illegal activities and what steps to take if they suspect these activities are taking place.

In the U.S., agencies like the CBP, USBP, ICE, and DEA use local media outlets and the Internet to inform local residents and others across the U.S. about illegal border activities. On February 3, 2006, ICE officials in San Diego, CA, set up a toll-free number (1-877-9TUNNEL) that the public can use if they have information about leads regarding underground passageways along the California-Mexico border. This initiative was implemented by San Diego’s multi-agency Tunnel Task Force, made up of ICE, DEA, and CBP agents.¹⁰⁷ In other sectors, the public may simply call the local CBP sector’s office phone number to report leads. Donald H. Kent, Jr., Assistant Secretary of Legislative and Intergovernmental Affairs at DHS, reported on February 27, 2007, that,

¹⁰⁶ United States. Department of Homeland Security. Special Assessment. Underground Tunnels: A Border Security Threat.

¹⁰⁷ “Tunnel Task Force Sets Up Toll-Free Line for Case Leads.” 3 Feb. 2006. U.S. Immigration and Customs Enforcement. 12 Dec. 2007
<<http://www.ice.gov/pi/news/newsreleases/articles/060203sandiego.htm>>.

“CBP is designating a single point of contact on all tunnel issues to ensure that accurate and consistent information is provided to legislators and the media.”¹⁰⁸

It is not currently known what steps, if any, Mexico officials take to assure that illegal border activities are reported and followed up on.

Legislation and Laws

Aside from direct action – tunnel detection, monitoring, and remediation – tunnels may receive indirect action in the form of legal scrutiny. The legislative approach taken by the U.S., Mexico, and Canada may produce a decrease in demand for tunnels or simply create increased penalties for those who construct or use them.

United States

With the increased occurrence of tunnels found along the U.S. borders since 9/11, U.S. legislators took recent actions to implement a tunnel prevention law. No previous law made it a crime to use, construct, or finance the illegal “construction of a tunnel or subterranean passage that crossed the international border” between the U.S. and another country.¹⁰⁹ Public Law 109-295, the Department of Homeland Security Appropriations Act for fiscal year (FY) 2007 (H.R.5441), made these activities illegal. The section of the bill on border tunnel prevention is Title 5 (General Provisions), Section 551. This bill was signed into law by President George W. Bush on October 4, 2006.¹¹⁰

The bill states that any tunnels not lawfully authorized by the Secretary of Homeland Security are subject to inspection by ICE and those involved with tunnels may be fined and imprisoned for up to twenty years for constructing or financing a tunnel. Punishment for other illegal border activities including utilizing a tunnel or passage for smuggling illegal aliens, goods, controlled substances, WMD (including biological weapons), or a

¹⁰⁸ “Department of Homeland Security Releases Details of Plan to Secure Unfilled Border Tunnels.” 6 Mar. 2007. Office of United States Senator Diane Feinstein. 12 Dec. 2007

¹⁰⁹ Department of Homeland Security Appropriations Act of 2007. Publ L. no. 109-295. 4 Oct. 2006. Stat. 120.1355. <http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_public_laws&docid=f:publ295.109.pdf>.

¹¹⁰ “H.R. 5441-109th Congress: Department of Homeland Security Appropriations Act, 2007.” 11 Dec. 2007. GovTrack.us. 11 Dec. 2007 <<http://www.govtrack.us/congress/bill.xpd?tab=summary&bill=h109-5441>>.

member of a terrorist organization are subject to a term of imprisonment that is twice as long as it would be if the unlawful activity did not occur in a tunnel or underground passageway.¹¹¹ For instance, the maximum punishment for smuggling illegal aliens into the U.S. is currently a ten-year prison sentence, but with the new law, the maximum sentence is twenty years if the unlawful conduct occurred in a border tunnel.

In addition, the new law enables the Federal Government to seize property or assets involved in the construction of an illegal border tunnel.¹¹²

Mexico and Canada

Currently, no laws exist in Canada or Mexico that make it a crime to build underground tunnels for illicit uses. Laws in both countries are also more lenient than in the U.S. for drug, weapons, and human smuggling.

Impediments to Action

In spite of the threat tunnels represent and a clear interest in removing said threat, a number of circumstances impede possible tunnel detection and monitoring solutions, whether technological or otherwise.

Native American Reservation Jurisdiction

In order to have a comprehensive approach to tunnel detection along the border, other areas like Native American Indian Reservations and conflicting jurisdictions must be considered. USBP agents already patrol within one of the largest reservations along the southwestern border, the Tohono O’odham reservation in Arizona (See Figure 14).¹¹³

¹¹¹ Dreier, David and Duncan Hunter. “Tougher Security Must Include Anti-Tunnel Bill.” San Diego Union-Tribune 20 Sep. 2006. 3 Oct. 2007

<<http://dreier.house.gov/inthepress/sdut092006.htm?d109:HR04830:@@P>>.

¹¹² “Border Tunnel Prevention Act of 2006.” 21 Sep. 2006. Congress.org. 3 Oct. 2007

<<http://www.congress.org/congressorg/issues/votes/?votenum=469&chamber=H&congress=1092>>.

¹¹³ “Tohono O’odham Nation Introductory Information.” 2003. Inter Tribal Council of Arizona, Inc. 12 Dec. 2007 <http://www.itcaonline.com/tribes_tohono.html>.

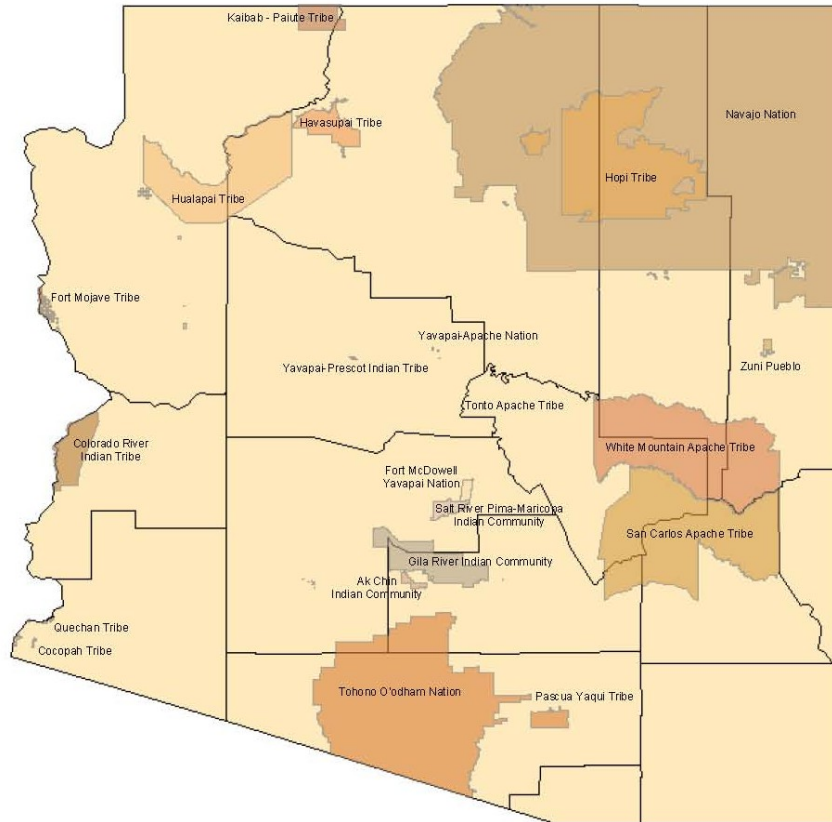


Figure 14: Map of Arizona with Native American Indian Reservations Shown

No tunnels have been found on this Native American ground to date. However, this has become one of the most heavily trafficked border areas in the country because of laws governing the reservation and restrictions on some USBP operations in this area due to tribal concerns. The Tohono O’odham have fought the construction of fencing on tribal land because of environmental and cultural concerns; also, the USBP has not been able to install permanent cameras or pave roads leading to and from the border. Current law states that the Secretary of the Interior may grant rights-of-way across tribal land with written consent of the tribe. Ultimately, the federal government holds all Indian lands in trust, and Congress may take lands for public purposes under just compensation as required by the Fifth Amendment.¹¹⁴

¹¹⁴ United States. Congressional Research Service. Border Security: Barriers Along the U.S. International Border. Blas Nunez-Neto and Stephen Vina. Washington, D.C.: Library of Congress, 2006. 12 Dec. 2006. CRS Web. 12 Dec. 2007 <<http://www.fas.org/sgp/crs/homesecc/RL33659.pdf>>.

Enforcement Jurisdiction

JTF-North plays an official support role in tunnel detection, and has unofficially taken responsibility as the tunnel detection technology clearinghouse in the U.S. However, per the Posse Comitatus Act, military forces cannot be directly involved in law enforcement along the border, but can support intelligence analysis, weapons and communications training, and can operate surveillance equipment.¹¹⁵ ¹¹⁶Unofficial roles breed uncertainty concerning where resources and information are stored.

Conflicts exist between the various agencies along the border with regards to tunnel detection and monitoring. While San Diego's Tunnel Detection Task Force operations are well executed and integrated across agencies, other cities have historically not been as successful. These established teams improve the process of tunnel detection information sharing and are an invaluable asset for standardization; they have yet to be successfully established in most other high-risk cities. Additionally, Memorandums of Agreement (MOA) and Memorandums of Understanding (MOU) do not currently exist to guide successful cross-agency cooperation in other cities.

Immediate Remediation

After tunnels have been identified, exploited, and analyzed, appropriate actions must take place to close, or remediate, the tunnels. This is usually done by USBP agents but sometimes, tunnels are filled or closed without their knowledge by local utilities companies and LEA investigations do not take place.¹¹⁷ Because of Occupational Safety and Health Administration (OSHA) regulations, tunnel detection technology cannot be tested on any of the tunnels that have been identified because of the danger they pose. The only tunnels left open to be tested on are currently located overseas.¹¹⁸

¹¹⁵ "About USNORTHCOM." United States Northern Command. 29 Nov. 2007
<<http://www.northcom.mil/About/index.html>>.

¹¹⁶ Andreas, Peter and Richard Price. "From War Fighting to Crime Fighting: Transforming the American National Security State." *International Studies Review* (Fall 2001): 31-52.

¹¹⁷ Rivera, Ramon. U.S. Border Patrol. Personal Interview. 22 Oct. 2007.

¹¹⁸ McKenna, Jason R. U.S. Army Corps of Engineers - Engineer Research and Development Center. Personal interview. 24 Oct. 2007 and 5 Nov. 2007.

Funding and Legislation

Government funding for a national tunnel detection project has been inadequate for various reasons, including missed budget proposals, interagency relationships, and simple oversight. The first formal attempt of organizing a tunnel detection project was the DHS Broad Agency Announcement (BAA) for a project entitled the “HSARPA BAA Tunnel 07-01A Tunnel Detection Technologies Project.” HSARPA is the Homeland Security Advanced Research Projects Agency, under the Department of Homeland Security’s Science and Technology Directorate.^{119 120} The BAA, a potential High Impact Technology Solution (HITS), was designed to provide proof-of-concept answers within one to three years, a high-payoff technology (revolutionary) breakthrough, “out-of-box” disruptive technologies, and an innovative solution. The BAA required that the first white paper submissions from “single entities or teams from private sector organizations, government laboratories, airport authorities, Federally Funded Research and Development Centers (FFRDCs) including Department of Energy National Laboratories and Centers, and academic institutions” be submitted by February 11, 2007.¹²¹ Proposal topics were open-ended and did not require any one technology in particular. Contracts were to be awarded on July 27, 2007 after full proposals had been submitted, but the second phase of the submittal process was cancelled and to date, funding of \$2 million for FY07 and \$1 million for FY08 have been proposed but not obligated.¹²² Current research is being done but is mostly funded by independent, outside sources. This is an indication that a tunnel detection technologies project is still in its beginning stages and needs to be adequately organized and funded.

¹¹⁹ “Welcome to the HSARPA Solicitations Portal.” 29 Nov. 2007. Homeland Security Advanced Research Projects Agency. 12 Dec. 2007 <<http://www.hsarpabaa.com/>>.

¹²⁰ Dizard, Wilson P, III. “DHS seeks ‘tunnel vision’.” 20 Feb 2007. Government Computer News. 12 Dec. 2007 <http://www.gcn.com/online/vol1_no1/43182-1.html?topic=it_management>.

¹²¹ “Department of Homeland Security Releases Details of Plan to Secure Unfilled Border Tunnels.” 6 Mar. 2007. Office of United States Senator Diane Feinstein. 12 Dec. 2007 <http://feinstein.senate.gov/public/index.cfm?FuseAction=NewsRoom.PressReleases&ContentRecord_id=6ad7439a-f31e-d51a-9147-49169d7eb0e0&Region_id=&Issue_id=>>.

¹²² Turner, Ed. “Tunnel Detect: Innovation/HSARPA HIT.” PowerPoint presentation for Science and Technology (S&T) Stakeholders Conference. United States Department of Homeland Security. 21 May. 2007 <http://www.homelandsecurity.org/StakeholdersMay07/Br56_Turner.pdf>.

In the House Appropriation Committee's Report 109-476 from the Department of Homeland Security Appropriations Bill for FY 2007, it was recommended that CBP budget money for tunnel remediation, or the filling of tunnels at entry and exit points once investigations by ICE, DEA, and other law enforcement agencies are finalized. CBP was funded \$2.74 million for FY 2007 for tunnel remediation, and the U.S. Army Corps of Engineers (USACE) has served as the contracting and technical agent for these projects.¹²³ The Committee also recommended that CBP, in concert with the SBInet program and DHS Science and Technology (S&T) Directorate, establish a program for detecting tunnels and addressing associated illegal activities.

In October 2007, the House of Representatives introduced H.R. 3916, a bill regarding tunnel detection technologies and related issues. As of the date of this report, the bill had been referred to the Committee on Homeland Security and the Committee on Science and Technology. The House bill would ensure that the Under Secretary for DHS S&T outlines manpower, training requirements, and operations and maintenance costs required for interagency or intra-agency research activities. The National Research Council was also authorized to assess the basic science research needs of border security applications three months after the enactment of this legislation, including detection and identification technologies which could include border tunnels. Most importantly, the legislation specifies that the S&T Under Secretary should research and develop technologies to permit detection of near surface voids such as tunnels, with an emphasis on real-time capabilities. In addition, it states that DHS should coordinate with other agencies, including DoD, and ensure integration of research and development activities.¹²⁴

Robert Hooks of DHS's Science and Technology Directorate (S&T) reported on November 15, 2007, before the House Committee on Science and Technology that if

¹²³ "Department of Homeland Security Releases Details of Plan to Secure Unfilled Border Tunnels." 6 Mar. 2007. Office of United States Senator Diane Feinstein. 12 Dec. 2007
<http://feinstein.senate.gov/public/index.cfm?FuseAction=NewsRoom.PressReleases&ContentRecord_id=6ad7439a-f31e-d51a-9147-49169d7eb0e0&Region_id=&Issue_id=>.

¹²⁴ United States. Cong. House. 110th Congress, 1st Session. H.R. 3916, A Bill to Provide for the Next Generation of Border and Maritime Security Technologies [introduced in the U.S. House; 22 Oct 2007]. 110th Congress. Congressional Bills, www.thomas.gov access. 11 Dec. 2007
<<http://www.access.gpo.gov/congress/cong009.html>; DOCID: f:s608is.txt>.

“funded in fiscal year 2009, we intend to study and characterize the geophysical characteristics of key border regions, examine the limitations of current detection methods, assist in advancing those detection methods, and examine the potential for new complementary detection methods.”¹²⁵ DHS S&T serves as the funding and procurement agency for tunnel detection technologies. No formal tunnel detection program currently exists in DHS, but DHS is looking for funding and other agencies have interest in the issue, both from a homeland security and a military, overseas perspective.

It should be noted that Tunnel detection *R&D* is currently being conducted but, just like those directly involved with detection and remediation efforts, researchers need adequate funding to effectively develop and test technologies on both a short-term and long-term basis. Army Lt. Col. Steve Baker of JTF-North said that until recently, several different organizations within the military have worked on tunnel or cave detection problems in a “stovepipe” manner. Within the federal law enforcement communities DHS is the lead. However, thus far, DHS has provided funding to CBP for tunnel remediation only.¹²⁶ Yet, funding is still desperately needed for R&D, manpower, and a tunnel detection technology border rollout.

The Department of Homeland Security Act for FY 2007 (H.R.5441) appropriated money for other DHS offices, but any funding that would have been allocated to tunnel detection would have fallen under allocations for the Office of the Under Secretary for Science and Technology. Funding could not be distributed to the Office until Congress reviewed a report addressing financial management deficiencies, improved management controls, and implemented performance measures and evaluations. In addition, Title II entitled Security, Enforcement, and Investigations, makes FY 2007 appropriations for CBP to hire additional Border Patrol agents, for automated systems, border fencing,

¹²⁵ United States. Cong. House. Committee on Science and Technology. Subcommittee on Technology and Innovation. Statement by Robert Hooks of DHS Science and Technology Directorate, United States House of Representatives, 110th Congress, 1st session, Nov. 15, 2007. Washington: GPO (2007) <<http://gop.science.house.gov/hearings/ets07/Nov15/hooks.pdf>>.

¹²⁶ Magnuson, Stew. “Hunters Unearth Smuggling Tunnels.” National Defense Jul. 2006. 29 Nov. 2007 <<http://www.nationaldefensemagazine.org/issues/2006/july/HuntersUnearth.htm>>.

infrastructure, and technology. This Act did not appropriate any money specifically toward tunnel detection technologies.¹²⁷

Unintegrated Border Fencing

Since 9/11, Congress has enacted laws to construct border fencing in certain high-traffic areas and near POE along the U.S.-Mexican border, but once these are built, tunnels are simply constructed to bypass the five to ten-foot extension of the fence that reaches underground. Some border fences have vibration technology underneath them to detect underground tunneling activity, but since several tunnels are built at angles or are several hundred feet underground, tunnels can easily circumvent detection near border fencing. Research is currently being conducted on more effective technologies in coordination with border fencing. This type of research and development should be a priority since much of the proposed border fencing along the U.S.-Mexican border has not yet been constructed.

In 1999, the U.S. government tested an underground fence along the U.S.-Mexico border to detect tunnel excavation. The USACE ERDC was involved with the testing of sensors that could differentiate the use of air hammers, hand picks, and other digging techniques. Dr. Lillian Wakeley of the ERDC described this technique as cost-effective and easy to implement.¹²⁸

Logistics of Tunnel Detection Training

Current tunnel detection technology operations require handling by trained experts for all phases: research, testing, equipment operation, data acquisition, and analysis. Most technologies in fact require expert eyes – trained geophysicists – in order to distinguish tunnel indicators from other sources of signal. With the introduction of tunnel detection operations to the mission set of the U.S. Border Patrol, agents will have to be responsible

¹²⁷ United States. Cong. House. 109th Congress, 2nd Session. Department of Homeland Security Appropriations Bill, 2007 [introduced in the U.S. House; 15 May 2006]. 109th Congress. Congressional Bills, GPO Access. 12 Dec. 2007

<http://frwebgate.access.gpo.gov/cgibin/getdoc.cgi?dbname=109_cong_reports&docid=f:hr476.109.pdf>.

¹²⁸ “The Security Situation in Rafah.” Oct. 2004. Human Rights Watch. 11 Nov. 2007

<<http://hrw.org/reports/2004/rafah1004/6.htm>>.

for the operation of the technologies and the analysis of the data retrieved. Supplying appropriate training to some subset of border agents such that expert eyes are no longer entirely necessary is a fundamental and difficult problem. However, the difficulty may be mitigated somewhat by simplifying the interface for technological tools and the eventual data products these tools produce.

Overview of Tunnel Detection Technologies

The clandestine tunnels found along the southwest border with Mexico and the northern border with Canada have sparked major interest in the development of geophysical technologies for their detection. Geophysics is not a new science, and a number of geophysical technologies already exist that are capable of detecting subsurface voids. Further development and refinement of these geophysical technologies is necessary in order to make them useful for tunnel detection as most have not reached the maturity to detect features as small and deep as typical smuggling tunnels under adverse conditions such as may exist on the border. In order to select appropriate technologies for tunnel detection, then, a characterization of technologies must be developed, referring to the previous definition of the physical characteristics of tunnels. A suitable characterization will include sensor capabilities such as sensing depth and precision, as well as trade-offs, such as costs and deployment concerns. An assessment of risk of tunneling activities along the border will provide a mechanism by which deployment can be limited to areas where technology is most needed, reducing both the cost and effort required while maximizing the likelihood of successful detection.

Technology Selection Methodology

To select a combination of technologies most suitable for tunnel detection along U.S. borders, a variety of factors and capabilities must be considered. Among these are:

- sensing depth
- precision
- cost
- deployment method
- ease of integration with other technologies and operations

Each of these considerations is explored further below.

Sensing Depth

The primary criterion used to select technologies for tunnel detection use is the depth of sensing penetration. Because tunnels discovered along U.S. borders to date have been in the range of three to eighty-five feet underground with an average depth of approximately twelve and one half feet and a standard of deviation of approximately fifteen feet, an adequate tunnel detection method should have a depth of sensing penetration which covers to at least one hundred feet underground. However, most technologies that are capable of sensing deeper underground suffer from poor resolution (or “clarity”) at shallow depths. This dichotomy presents a challenge for the selection of proper tunnel detection technologies. Data suggests that the deeper, improved tunnels typically used for drug smuggling present a greater threat than the shallow, unimproved tunnels typically used for human smuggling. This distinction allows the selection process to be focused on technologies with a greater penetrative depth as a general positive. In order to facilitate location of more shallow tunnels, alternate recommendations will be necessary.

Precision & Accuracy of Output

Following the sensing depth, the precision and accuracy of sensor output is the most significant selection consideration. Precision is a measure of the “exactness” of output; accuracy is a measure of the factuality of output.

Assuming that an anomaly detected is a tunnel, the technology in use must be able to then calculate the location and depth of the tunnel. Due to the large cost of boring into a tunnel or conducting a search operation for the exit point, the calculation of the tunnel’s location must be as precise as possible, both in terms of latitude and longitude (or above-ground location) and depth. However, there exists a trend in current technology that represents an inverse relationship between sensing depth and precision. That is, technologies with deeper sensing capabilities tend to have output that is less spatially exact (precise). This trade-off must be considered during the selection process.

In order to effectively search for and detect tunnels, a technology must also be highly accurate – that is, present a relatively low rate of false positives and negatives. False positives are defined as the identification of a tunnel when no tunnel actually exists. False negatives are identified as the failure of the technology to identify a tunnel that exists in

the area being scanned. A high rate of either false positives or negatives represents a fundamental failure of the technology to perform the function that it is intended to do.

Cost

As with any operation being considered for deployment, cost is a major factor for consideration. For the selection of technologies, only the costs of the individual equipment will be considered. Associated costs (deployment, personnel, maintenance, etc.) will be discussed during the selection of the deployment strategy. Due to the fact that most technologies considered are fairly new to the market, the costs associated with most of the sensors are still fairly high. However, due to the wide range of current COTS sensor technologies, only rough cost estimates were used during the selection of applicable technologies. Tunnel detection technology costs were compared by categorizing the technologies based on cost per distance scanned.

Ease of Deployment

The final criterion used to select tunnel detection technologies is the ease of deployment. Since the problem of clandestine tunnels has been present for some time and is growing at a rapid rate, a fast deployment schedule is preferred. A deployment schedule will consist of acquiring the equipment, training personnel, and actual deployment into the field. All technologies considered were analyzed to determine the difficulty that would be encountered when deploying each technology. It is important to note, technologies that display exceptional applicability to the field of tunnel detection will not be discarded due to difficult deployment requirements. The ease of deployment for each technology will be considered separately, while the recommended deployment strategy will be discussed in a later section.

Sensor Types & Applicability

Based on the preceding criteria, various sensor types may be filtered as more or less appropriate to tunnel detection and monitoring applications. Each sensing technique that follows exploits a particular physical feature or phenomenon associated with underground tunnels: small local variations in gravity, resistivity, earth vibrations, densities, conductivity, and motion.

Gravity Surveying

Gravity is a measurable attractive tendency between bodies of mass. The Earth is commonly regarded as a single massive body, and therefore the attractive tendency it exercises over nearby masses is considered to be a single constant. Measurements of the gravitational field do vary slightly, however. These variations may be caused by a variety of factors – elevation of the surface, altitude of equipment used to take measurements, and variations in the amount of mass between the Earth’s center and surface. This last source of variation is of particular interest in tunnel detection, as a tunnel is essentially mass that is “missing”. The amount of missing mass due to a tunnel is small compared to the overall mass of the earth, meaning variation in the gravitational field will also be small and equipment to measure the variations must be highly sensitive.

Because variations in the gravitational field may be caused by changes in elevation, location and elevation at the measurement site must be known precisely – to within 12 meters and 4 centimeters, respectively, for gravity surveys returning measurements on the order of 0.1 gravitational units.¹²⁹ For microgravity surveys that return measurements on the order of 0.01 gravitational units (precise enough to detect a tunnel), location and elevation readings to approximately 1.2 meters and 0.4 centimeters respectively (or an order of magnitude more precise) would be required to calibrate the measuring equipment. Given data from many measurements taken with well-calibrated equipment, the product of these measurements (a gravity survey) can show subsurface anomalies like tunnels to a depth of 100 feet. The precision of this method, however, is directly inverse to the sensing depth, unless the size of the features (tunnels) is proportionally larger.

Readings indicating gravitational anomalies may also be generated by movement of massive objects as well as by local vibrations. Cars on nearby roads and vibrations from wind in particular can register as gravitational variations. These sources of interference complicate the integration of this technology into a solution set, particularly in urban areas.

¹²⁹ Sharma, Prem V. Environmental and engineering geophysics (Cambridge: Cambridge University Press, 1997).

Advantages

- Use is not restricted by soil type;
- ground and aerial surveying is possible (though currently, non-stationary applications are impractical);¹³⁰
- measurements are relatively easy to make.

Disadvantages

- Results can be ambiguous (substantially different mass distributions can provide nearly identical gravitational potential readings);¹³¹
- measurements are affected by tidal drifts and changes in ambient temperature and pressure (though digital equipment can make compensation for these factors more simple);¹³²
- measurements require exact (to within an inch or less) calibration of altitude and elevation, lowering viability in areas of uneven terrain;
- sensitivity does not allow for the detection of small, deep tunnels;
- data acquisition is slow (approximately 5-30 minutes per point).¹³³

Assessment

Gravity gradiometry has shown some promise in testing phases, as well as for other applications. Although it satisfies one of the primary criteria for an optimal solution for tunnel detection – depth of sensing penetration – gravity gradiometry currently exhibits a lack of sensitivity, high rate of false positives and negatives, stringent calibration requirements, and extremely slow data acquisition. The technology is subject to additional interference from industry and automobiles, making potential deployment to

¹³⁰ “Exploration Trends & Developments in 2005: Airborne Geophysical Surveying.” Supplement to The Northern Miner Mar. 2006: 5-12.

¹³¹ Sharma, Prem V. Environmental and engineering geophysics (Cambridge: Cambridge University Press, 1997).

¹³² Sharma, Prem V. Environmental and engineering geophysics (Cambridge: Cambridge University Press, 1997).

¹³³ Ballard, R.F., Jr. Tunnel Detection. U.S. Army Engineer Waterways Experiment Station. Dec. 1982.

urban areas difficult. These negative factors make gravity gradiometry unsuitable for tunnel detection, pending further research and development.

Resistivity

Electrical resistivity is a measure of the opposition to the flow of electrical current in a material. Highly conductive materials, such as the metals used in electrical wiring, have a relatively low resistivity. Closer to the other extreme, air has a relatively high resistivity. To measure the electrical resistivity of an area, a high voltage direct current is applied through ground probes. Measurements are then taken of the resistance between the probes. Variations in resistance readings are expected to be small locally, with larger differences appearing gradually over large distances; therefore, where resistance values contrast highly, a subsurface anomaly (such as a tunnel) is likely. Resistivity techniques allow for sensing penetration to depths greater than 100 feet with reasonably high accuracy, and have been used in the past to locate groundwater, chemical spills, and larger voids.¹³⁴

Although changes in the resistivity of the ground are expected to be small or gradual, buried features such as utilities can cause local variations that are very large. Therefore, application of electrical resistivity surveying to urban environments requires a thorough understanding of existing subsurface infrastructure in the location of interest. Additionally, features above the ground – including buildings and border fencing – can interfere with resistivity measurements.

Advantages

- Quick, shallow measurements are possible via ground vehicles;
- anomaly depth can be determined as a function of probe spacing;
- cost is relatively low, compared to other geophysical techniques;¹³⁵
- data analysis requirements are low.

¹³⁴ Sharma, Prem V. Environmental and engineering geophysics (Cambridge: Cambridge University Press, 1997).

¹³⁵ Sharma, Prem V. Environmental and engineering geophysics (Cambridge: Cambridge University Press, 1997).

Disadvantages

- Moisture content in soil can affect measurements drastically;¹³⁶
- cities require the use of alternate (and less reliable) equipment;
- Resolution is inadequate for identifying subtle resistive differences.

Assessment

Resistivity surveying has been used for a wide variety of applications for many years. The success of the method for tunnel detection, however, has been limited. There is no argument that the physical principles behind this technology are legitimate for subsurface imaging; the difficulty lies in the method's resolution. At present, equipment has not been designed with the sensitivity to detect the minute resistivity variations presented by small border tunnels. A solution covering a large area like the border would require access to install ground probes – preferably permanently – which would ultimately be cost-prohibitive given fundamental inability of the technology to detect smaller subsurface features. After further refinement and testing with the specific purpose of tunnel detection in mind, resistivity may prove more suitable for application to the problem.

Active Seismic Surveying

Seismology is the study of earthquakes and, more generally, the propagation of elastic waves through the ground. With earthquakes as an extreme example, elastic waves can be understood as the source of ground vibration. A seismic survey has application to tunnel detection. In fact, seismic technologies have been used for subsurface imaging since the beginning of near-surface geophysics' existence as a science.¹³⁷ Active surveying relies on generating a wave source at the surface, often by simply thumping the ground. This thump generates elastic waves which propagate through the ground and are reflected at changes in density in the subsurface. Geophone sensors near the surface record the reflected waves. In this way an image of the subsurface based on reflection times is

¹³⁶ Sverko, Elvis R. "Ground Measuring Techniques: Electrode Resistance To Remote Earth & Soil Resistivity." ERICO, Inc. Facility Electrical Protection, U.S.A. Feb. 11, 1999.

¹³⁷ Steeples, Don W. "Near-surface Geophysics: 75 Years of Progress." University of Kansas. 1 Sep. 2007 <<http://tle.geoscienceworld.org/cgi/reprint/24/Supplement/S82.pdf>>.

formed.¹³⁸ Geophone sensors can be placed in the ground permanently, temporarily, or can be pulled on a streamer for mobile readings.

Unwanted background noise can also create elastic waves in the subsurface, thus introducing unwanted interference in seismic readings. Common sources can include moving vehicles and construction. In active sensing, the best method for overcoming such forms of interference is performing readings at times when these noise sources are minimized.

Advantages

- Depth of Penetration can reach hundreds of feet;¹³⁹
- use is not restricted by soil type;
- new and old data can be compared for change detection.

Disadvantages

- Local vibrations/seismic activity degrade data;
- cost of continuous monitoring is high;
- data processing can be computer intensive;
- data interpretation lacks maturity.

Assessment

Active seismic surveying has been a primary method for subsurface imaging for many years. However, the precision of active seismic data is not at a level which can accurately detect smaller features like tunnels. There are considerable costs involved in covering any large area with seismic technology. Costs could be lowered by taking readings less often – using the data for change detection rather than continuous monitoring. The technology is promising both from a research and development standpoint and for use in verification

¹³⁸ Sharma, Prem V. Environmental and engineering geophysics (Cambridge: Cambridge University Press, 1997).

¹³⁹ Gritto, Roland. "Subsurface Void Detection using Seismic Tomographic Imaging." Lawrence Berkeley National Laboratory. 5 Oct. 2007 <<http://www.osti.gov/bridge/servlets/purl/813398-vSsE7T/native/813398.pdf>>.

of tunnel locations.¹⁴⁰ However, the requirement for active involvement in data acquisition limits the applicability of this method.

Passive Seismic Surveying

Passive seismic surveying is based on the same principle as active surveying: the propagation of elastic waves through the subsurface. Passive sensing differs in that it monitors for seismic activity caused by digging and tunnel traffic. Passive monitoring also uses geophones, most usefully those that isolate the vertical, longitudinal, and transverse components of a wave signal, thus effectively locating the signal source. Passive methods have the ability to penetrate to moderate depths – at least 40 feet – with a great deal of precision.¹⁴¹

As in active sensing, unwanted noise sources may generate interference, particularly in urban areas. Filtering out this unwanted component of the signal is feasible at the data processing stage; in fact, research in this area is in process, recommending this method for intensive application.¹⁴²

Advantages

- Lowest number of false positives and negatives;¹⁴³
- location and activity identification is possible through data processing;
- subsurface can be continuously monitored for activity

Disadvantages

- Local vibrations/seismic activity degrade data;
- depth of penetration is limited to shallow tunnels;
- cost of permanent installation and monitoring is relatively high;

¹⁴⁰ Corcoran, M. K. and Grau, T. H. “Subsurface Site Characterization – Proceedings of Research Needs Workshop.” U.S. Army Corps of Engineers. Dec. 1994.

¹⁴¹ McKenna, Jason R. U.S. Army Corps of Engineers - Engineer Research and Development Center. Personal interview. 24 Oct. 2007 and 5 Nov. 2007.

¹⁴² Corcoran, M. K. and Grau, T. H. “Subsurface Site Characterization – Proceedings of Research Needs Workshop.” U.S. Army Corps of Engineers. Dec. 1994.

¹⁴³ McKenna, Jason R. U.S. Army Corps of Engineers.

- data processing can be computer intensive.

Assessment

Passive seismic monitoring has been successfully undergone a considerable amount of testing for tunnel detection, proving to be the most accurate sensing technology available. Temporary or permanent installation options are viable, but permanent installations involve considerable costs, particularly over large areas. Current work in data interpretation continually improves results from this method, recommending it above most other technologies for application in tunnel detection and monitoring.

Ground Penetrating Radar

Ground penetrating radar (GPR) is a common method for subsurface imaging, operating on wave reflection principles similar to those used in seismic sensing methods. However, instead of elastic waves reflecting on changes in density, GPR relies on the reflection of electromagnetic waves at the boundaries of materials with different dielectric constants, or the relative magnetic permeability of the materials.¹⁴⁴ A GPR unit transmits pulses of high frequency electromagnetic waves into the ground through an antenna and receives the reflections of those waves, producing high resolution images of the subsurface by measuring the difference in reflection time from point to point. Because the magnetic permeability of air will be significantly different from the soil around it, GPR can effectively detect some air voids.

Numerous commercially produced GPR units exist, targeted to specific applications; subsurface void detection under concrete is in fact a commercial specialty of GPR. The GPR unit itself is often mobile and cart-mounted, placing the transmitter and receiver very close to the ground as is ideal for GPR measurements. Depth of penetration varies from region to region and is based on the electrical conductivity of the ground. More conductive ground absorbs the emitted energy more quickly, leading to a lower depth of penetration.¹⁴⁵ This impedes application over moist clay soils, which are far more

¹⁴⁴ “Dielectric Constant.” 27 Apr. 2001. WhatIs.com. 17 Sep. 2007 <http://searchcio-midmarket.techtarget.com/sDefinition/0,,sid183_gci548179,00.html>.

¹⁴⁵ “Ground Penetrating Radar – principles.” GeoModel. 17 Sep. 2007. <<http://www.geomodel.com/gprtext.htm>>.

conductive than dry soils. Increased penetration depth can be attained if the frequency is lowered, but resolution suffers in the process. Additionally, unknown buried utilities and other buried metal can interfere with GPR's ability to detect anomalies of interest. These factors limit application to areas where underground infrastructure can be predicted.

Advantages

- Data acquisition is mobile based and rapid (.8-8 kHz);¹⁴⁶
- resolution can be very high, given the proper subsurface conditions;
- commercial units are widely available and relatively low cost;
- particularly successful detecting voids under pavement.

Disadvantages

- Penetration depth suffers greatly in moist soils;
- readings are susceptible to interference from underground metal;
- interpretation of data can be difficult.

Assessment

GPR is a commercially available solution commonly used for a variety of applications. Lack of depth of penetration in moist soils limits its potential applicability. This factor is especially important to the application of tunnel detection, since the soil in southern California, an area with an extensive history of clandestine tunneling, is largely moist clay. This alone nearly eliminates it as a possible solution for detecting deep tunnels. However, GPR is particularly successful detecting voids directly under concrete. This success recommends the technology for use in tunnel detection because many shallow tunnels use street surfaces as ceilings. For verification in urban areas, this capability is indispensable.

¹⁴⁶ "Ground Penetrating Radar." 19 Sep. 2007. Clu-in.org. 25 Sep. 2007 <<http://www.clu-in.org/char/technologies/gpr.cfm>>.

Electromagnetic Induction

Electromagnetic (EM) induction technology is a relatively new ground surveying technique capable of subsurface imaging. EM surveying methods use a transmitter coil/antenna to generate an electromagnetic field that propagates into the ground. This field in turn induces a current in the surrounding subsurface, which then creates a secondary electromagnetic field that propagates back to a receiver on the surface. The receiver coil/antenna senses and records this secondary field. A component of this field is analyzed and used for to image the subsurface. Its magnitude is linearly proportional to the conductivity of the ground; therefore, buried cables or other metal objects will show significant contrast with this method. Additionally, salt and moisture, which have conductivity significantly higher than that of average soil, accumulate at the bottom of tunnels, making it possible to detect tunnels with no metal.¹⁴⁷ A typical EM unit is carried in hand or pulled on a trailer. Depending on design, EM units can sense to depths approaching 100 feet or focus on shallow targets.¹⁴⁸ These types of sensors lack the consistency and reliability necessary to detect tunnels in a single pass, making the technology more suitable for change detection over time.

Like GPR, EM induction sensing is affected by buried utilities, and also EM sources other than the transmitter coil. However, EM induction is particularly good at detecting even very deep tunnels with improvements, as the improvements often contain wiring or other metal features. This feature recommends the technology for limited application in a change detection capacity along the border.

Advantages

- Data acquisition is rapid (2-12 mph);¹⁴⁹
- unit does not have to be in direct contact with ground;
- depth of penetration has potential to reach 100 feet;

¹⁴⁷ Stolarczyk, Larry G., et al. "Detection of Underground Tunnels with a Synchronized Electromagnetic Wave Gradiometer." Stolar Research Corporation. Apr. 2005.

¹⁴⁸ Stolarczyk, Larry G., et al. "Detection of Underground Tunnels with a Synchronized Electromagnetic Wave Gradiometer."

¹⁴⁹ Parkman, Kevin. Personal interview. 5 Nov. 2007.

- commercial units are available, thus is ready for deployment.

Disadvantages

- Current sensitivity struggles to detect shallow non-conductive tunnels;
- measurements based on conductivity, can give false readings due to extraneous metal in the ground;
- receiver has to have good signal to noise ratio otherwise secondary field may be hard to detect.

Assessment

Electromagnetic induction boasts fast to operation, great depth of penetration, and even the possibility of remote operation on a UGV. It is not a silver bullet for locating tunnels, however, as it produces a number of false positives and false negatives and also has a great deal of trouble identifying small, shallow, unimproved tunnels. Used in combination with other options, however, electromagnetic induction methods are extremely promising for tunnel detection.

Motion Detectors

In the case of cross-border sewer or drainage systems, existing cross-border drainage systems (such as that in Nogales, Arizona) require another type of sensing device. Because the existence of subsurface air voids is known, imaging is not an appropriate solution; similarly, permanent arrays of sensors to listen would be inappropriate as they could not be placed on the Mexico side of the border. Instead, monitoring for traffic *through* drainage tunnels is required. Commercially available motion detectors have the ability to easily monitor for human motion. Often these commercial motion detectors are used for applications such as door sensors, outdoor lighting systems, as well as for a variety of security applications. There are three basic types of commercial motion detectors including infrared, wave reflection, and combinational.

Infrared

Infrared technology passively detects differences in heat. This detection is accomplished by measuring the amount of infrared energy emitted by an object, which is directly

related to the object's temperature. A typical infrared sensor focuses the infrared energy in a certain range of view in, using a fresnel lens.¹⁵⁰ It then it monitors for a certain magnitude of change in detected energy (or temperature) over a specified time period. When a human walks by, the sensor registers a significantly warmer temperature than that without human presence, and can transmit a signal indicating detected motion. Infrared sensors are widely available for a number of similar applications, and so would require little modification to make them applicable for this purpose.

Wave Based

Wave based solutions – microwave or ultrasonic motion sensors – work by sending out wave pulses. These invisible, inaudible waves reflect off of objects in their field of view and return to the sensors in a certain amount of time. The amount of time required for a wave to return is proportional to the distance to the nearest object. When an object moves in front of a wave based motion sensor, the sensor receives reflected waves at a different rate and can signal detected motion. These types of sensors are also widely available, and would similarly require little modification for application to drainage system monitoring.

Combinational

A variety of companies make combinational motion detectors, which combine both wave based and infrared sensor technology to produce more accurate motion and heat detection. The goal of combining the two technologies is to reduce the number of false alarms. This can be accomplished with a sensor which operates both infrared and wave based sensors continuously, but a significant power savings can be accomplished by running the wave based sensor only when the infrared sensor is triggered, simply for intrusion confirmation.¹⁵¹ This type of combinational solution improves overall accuracy and precision while minimizing power consumption. Many of the sensors are equipped with the ability to ignore smaller intruders, such as pets, which also reduces the number of false positives.

¹⁵⁰ "How Infrared Motion Detector Components Work." Aug. 2007. Glolab Corporation. 1 Nov. 2007 <<http://www.glolab.com/pirparts/infrared.html>>.

¹⁵¹ "How PIR Motion Sensors Work." Gadget Shack. 12 Nov. 2007 <<http://www.gadgetshack.com/motionsensor.html>>.

Assessment

Both types of motion detection are based on proven principles; they simply work. A combinational sensor will yield the most accurate results, with minimal additional cost. All types of sensors are widely available in many commercial forms at minimal cost per unit.¹⁵²

It is likely that a solution specific to the problem in Nogales will require development to be successful. While the core technologies and even combinational sensors already exist, the installation requirements dictate a solution that is durable, fixed, hidden, and waterproof. To ensure they are not identified, the detectors must be disguised; each site will have to be surveyed for optimal installation locations, as conditions will vary.

Power consumption is also a critical consideration for this technology. While batteries and solar power are possible solutions for powering other sensors, the fixed and underground installation requirements of these motion detectors precludes these options. Hydroelectric charging of batteries bears investigation.

Deployment Platforms & Options

Following the identification of appropriate detection technologies, the next step in the recommendation process is to identify a deployment strategy that will be effective and efficient. An appropriate deployment strategy will provide an effective means for the technologies to be operated at their full capacity, while not hampering current border security operations and capabilities.¹⁵³ The deployment strategy will be based on the capabilities of not only the technologies used, but also on the capabilities of the individuals and equipment/machinery used to get the technologies into the field.

Selection of the deployment strategy will be based on tunneling risk level, cost, surveillance area, and adaptability. The ideal deployment strategy will minimize cost and personnel requirements, while covering a large surveillance area and be receptive to any operational changes that may be required in the future. The selection considerations and requirements will be discussed in the following sections.

¹⁵² "Motion Detectors." Home Security Store. 27 Dec. 2007 <<http://www.home-security-systems.net/motiondetectors.php>>.

¹⁵³ Rivera, Ramon. U.S. Border Patrol. Personal Interview. 22 Oct. 2007.

Tunnel Risk Level

Efficient use of tunnel detection technologies will require the use of a tunneling threat or risk level. It can be expected that the areas that have a greater risk of tunneling activity will require more attention than the areas that have a lower risk of tunneling activity. The existence of these two different classifications warrants two entirely different deployment strategies, one for each area; or one strategy with separate tiers of deployment levels. In either case, a technological combination of tunnel detection methods will be used, as indicated by previous sections.

These combined technologies will be integrated into the deployment strategy in differing ways that suit each of the technologies individual strengths and weaknesses. This integration will ensure that all the technologies perform at their full capacity, which will provide the most concise and accurate data.

Based on preliminary risk level analysis, two separate deployment strategies will be formulated: one for areas identified as having a lower risk of tunneling activity, and another for areas with a higher risk or tunneling activity.

Cost

One of the largest factors for consideration in any project is the cost of implementation. This section will discuss the cost considerations of an effective tunnel detection technology deployment strategy. It should be noted that this section will not consider the costs of the individual technologies themselves, as this was discussed in a previous section.

The largest contribution to the cost of a deployment strategy will most likely be the labor costs for the personnel required to facilitate and operate the technologies. For this reason, the selected deployment strategy will need to require as few personnel as possible. By increasing the amount of autonomy in the strategy, costs will be reduced. Therefore, the inclusion of unmanned vehicles and unmanned sensor arrays will be more preferable than a manned operational method. However, it is important to note that some degree of personnel in the field will be required, due to either a possibility for danger to the equipment or the uselessness of a permanent installation.

The other two major cost factors to consider are the cost of vehicles (manned and unmanned) used to transport the technology during operation and the installation cost of a permanent sensor array. It is recommended to keep vehicle costs down by only utilizing as few vehicles as possible in each region. These regions will most likely be defined by the government agency or department that will manage and operate the tunnel detection technologies. The installation cost of a permanent sensor array also has to be considered when selecting a deployment strategy. Unfortunately, the cost of installation will be greatly based upon the actual sensors selected for the installation, and the depth of installation. It is important to note, however, that there will be an inverse relationship between cost and effectiveness of a permanent sensor array. Therefore, it is recommended that any sensor array selected be installed in a manner that will promote the most accurate tunnel detection results, although the cost of installation may be higher.

Surveillance Area

It is important to recognize that all deployment methods will have limitations on the amount of ground that they will be able to cover.¹⁵⁴ However, it is important to select a deployment strategy that will cover the most ground, while not sacrificing any of the gains made from the other selection criteria. While a permanent sensor array will be capable of handling a large area, the readings from its sensors will need to be augmented by mobile scanning performed by other technologies. In order to increase the amount of area that can be covered by one unit, the use of ground vehicles (manned and unmanned) is both warranted and recommended. Since specific jurisdictional regions have not yet been defined, it is difficult to specify exact recommendations as of yet. However, the basic concept of scanning an entire region in as little time as possible should be adhered to whenever possible. Therefore, technologies that are more easily integrated into mobile platforms, such as GPR and electromagnetic gradiometry, are highly recommended.

¹⁵⁴ McKenna, Jason R. U.S. Army Corps of Engineers - Engineer Research and Development Center. Personal interview. 24 Oct. 2007 and 5 Nov. 2007.

Adaptability

The final deployment strategy selection criterion to be considered is the adaptability of the deployed system. It is safe to assume that the individuals who are responsible for the construction of the tunnels will adapt their methods of construction, either through location or type of tunneling, in reaction to a successful tunnel detection technology network. Therefore, a successful tunnel detection technology network must also be able to adapt around the changing strategies of the tunnel constructors. Unfortunately, this change will more than likely be reactive, as changing the detection method prior to a change in the tunnel methodology would not be prudent. Any changes or adaptations that may need to occur should be dictated by alterations in the tunnel risk level assessment. Since the tunneling risk level is the foundation for the recommended deployment strategy, any changes in the latter must be as a result of changes in the former.

It is safe to assume that the mobility and adaptability of a technology will share a direct relationship with one another. That is, the more mobile a technology is, the more quickly the technology will be able to adapt to changes in operational protocol. Once again, GPR and electromagnetic gradiometry are highly recommended.

By considering the criteria listed above, the authors developed a recommended deployment strategy for the tunnel detection technologies selected for use. The recommended strategy and the reasons for its selection will be discussed below.

Data Handling

Data cannot simply exist in a cloud of sensors. In order to optimally use the information gleaned from systems of sensors, data must be properly retrieved, stored, analyzed, and acted upon. In order for these actions to occur, priority should be placed upon quality of information, fusion with other sources of data, and security of both raw data and finished data products, as follows.

Quality of Information (QoI) Criteria

The aim of any system of tunnel detection and monitoring is to provide the best data possible about the construction, existence, and use of tunnels. Parameters for quality data include:

- Timeliness, or the amount of existent delay before relevant data is available to an end-user;
- accuracy, or the baseline requirement that data be factual and correct;
- reliability and confidence, or the extent to which data can be trusted based on rates of false-positives and false-negatives;
- throughput, or the rate at which data can be collected;
- cost, or the economic outlay required to sustain data collection and analysis efforts;
- completeness, or the continuity of data in both time and space;
- relevancy, or the interest-level of filtered and returned data;
- usability, or the ease with which data may be understood and acted upon.¹⁵⁵

These parameters become the foundation of a search for appropriate technologies to integrate sensor data. In fact, the criteria used to select sensor technologies speak directly to these parameters: aside from those directly matching in name and concept, sensing depth and ease of deployment are both a timeliness and cost metric. Along with those named in sensor selection criteria, many QoI criteria are necessarily dependent on the particular sensors and physical methods used on the ground. It cannot be stressed enough, however, that data acquisition at the sensor level is not a complete solution to delivery of quality information. Appropriate transport, processing, analysis and storage of data have the potential to affect each and every parameter for QoI listed.

A few statements can be made concerning appropriate adherence to these criteria, specifically with tunnel detection and associated data handling in mind. First, it is suggested that even with the best excavation tools, tunnels with significant improvements take no less than one month for complete construction.¹⁵⁶ Therefore, acquisition of a data

¹⁵⁵ Bisdikian, Chatschik. "Quality of information trade-offs in the detection of transient phenomena." Proc. SPIE Int. Soc. Opt. Eng. 6562 (2007): 656214.

¹⁵⁶ McKenna, Jason R. U.S. Army Corps of Engineers - Engineer Research and Development Center. Personal interview. 24 Oct. 2007 and 5 Nov. 2007.

set modeling the subsurface along the border could be considered timely if completed within a single month. To support timely action on acquired data, throughput must also be sufficient to make this data – and final products of analysis – available within the one month time frame. Second, until such a time that sensor data is sufficiently transparent, expert analysis will be required for any acceptable level of confidence in data.

Next, a “complete” set of data can mean a range of things, from acquisition of data along every inch of the border (which would be so cost-prohibitive as to be impossible) to acquisition in every place where tunneling is *possible*. Several subsections of the border are in fact impassable to tunneling efforts (due to the presence of rivers, instability of soil, and so on); acquisition of data at every place where tunneling is *possible* is sufficiently complete. Discarding these impassable areas reduces overall costs.

A set of complete data, however, may bear no relevance if it does not indicate the features it seems to indicate. For example, technologies which detect subsurface voids may indicate a void in a particular place; if that void is in fact a natural formation (i.e., a cave or sinkhole), the data is ultimately not relevant for discovery of a clandestine operation. Therefore, establishing a baseline of the geophysical properties of the border is necessary so that historical comparison can filter out pre-existing or naturally occurring features.

Finally, a “perfect” set of data will not serve the interests of law enforcement officials if the information is not presented in such a way that it is usable. Usability requires a solid set of data to begin, appropriate analysis of this data, and finally, an eye for production quality in delivery of a final product that is clear, concise, and complete.

Therefore, in order to optimally attain and handle tunnel detection and monitoring data, all of the metrics above must be refined to the highest standard. The best possible system would employ the most accurate sensing equipment in data collection over the entire region of interest on a monthly basis or more often. Data would then be pre-filtered for relevance, analyzed against false alarm calculations for maximum confidence, and presented in a clear, concise format to later act upon.

Security

Security, in the context of tunnel detection and monitoring, has many meanings. First, tunnel detection has security implications – that is, proper execution of tunnel detection and monitoring has the potential to increase the security of our national interests. Second, technology-based tunnel detection provides security for ground personnel. Tunnel detection based on technology reduces personnel exposure to direct conflict, on U.S. borders or elsewhere. Finally, tunnel detection has security *requirements*; tunnel detection and monitoring data must be kept safe and out of the hands of those with other interests. It is this last that is salient in a discussion of data handling.

There is a concern in any operation which gathers data that the data gathered can be abused, whether by internal or external actors. To remedy this, several safeguards are necessary to ensure the truth and appropriate use of tunnel detection and monitoring data.

First, sensors should be immune to direct injection of data. Direct injection of data involves accessing a sensor and either masquerading conditions that suggest false data, or inserting pre-recorded signal between the sensing and communication components. This is a solved problem in telecommunications; equipment is simply enclosed in a box with tamper alarming.

Second, the network should be immune to sensor masquerading. Sensor masquerading involves accessing the communications network for the sensors, establishing a non-sensor piece of equipment as a sensor by faking data properties and identifiers, and injecting an unwanted signal into the system. This signal can take many forms – false data, injection of arbitrary code to repurpose real sensors, network impairment, and theft of signal. Security measures to combat such masquerading are neither simple nor within the scope of this report; it does, however, serve to mention the need for such measures.

Third, raw data should ideally be stored in a static format once it is returned to storage and processing facilities. It is possible to analyze data and produce final products without editing raw data, either by working with editable copies of protected data, or by applying non-destructive editing “layers” to read-only master data.

Fourth and finally, appropriate security practices should be employed at storage and processing facilities. At storage and processing facilities, the primary concerns are for

theft, deliberate misinterpretation, or misuse of data. All of these concerns can be addressed by appropriately screening personnel and limiting outgoing data.

Transmission

Autonomous function is ideal when deploying large numbers of sensors in an environment that is hostile to monitoring attempts. Operational autonomy – or selection of sensors which do not require human operation – is only one facet of autonomous function, however; sensors must also have the capability to transmit data collected. Current tunnel detection efforts have collection of data from sensors executed by hand by personnel on the ground, but this is neither a necessary condition nor likely to be a permanent one.

Network Solutions

Retrieval of sensor data requires sensors to have some variety of communications capabilities, as well as a network to support these capabilities. The specific communication and networking strategies selected will vary based on the local environments into which the sensor are placed, distances between sensors and networking equipment, and the volume of data to be transmitted.

As a basic measure, sensors can communicate directly with a central server. In this situation, on-sensor pre-processing may be desirable, after which the sensor can transmit a subset of its data that is “of interest”. Alternatively, “dumb” or signal-agnostic sensors can simply communicate *all* collected data. In either case, sensors can also communicate with an intermediate server for further processing before data is transmitted to a central, human-accessible location. Intermediate processing servers can remove a need for costly on-sensor processing, reduce sensor-to-server distances, and lighten the processing load placed on a central server and analysis personnel.

An alternative to these hierarchical approaches is networking sensors in an ad hoc or peer-to-peer (P2P) network. P2P networks allow sensors to communicate information with adjacent sensors. Strengths of this approach are numerous; distributed data analysis, combination of local data sets, and data redundancy become possible. Also, power requirements for data transmission can be significantly reduced using P2P principles.

Combinations of direct, tiered, and P2P approaches are also viable. Selection of a particular method of communications is largely dependent on local and mission variables. Where a networking backbone exists with sufficient bandwidth to handle the quantities of data generated by sensors, any of the approaches alone or in combination may be used.

Current Network Availability on United States Borders

On both the U.S.-Mexico and U.S.-Canada borders in areas of interest for tunnel detection, a wired or wireless network backbone exists in multiple forms. Existent infrastructure in both commercial and government-operated networks can be used for transmission of tunnel detection and monitoring data. An example of a network that is particularly suited to this application is DHS OneNet. DHS OneNet is an integrative network joining CBP, ICE, and Coast Guard information assets.¹⁵⁷ Existing architecture under this program allows for connection of ground sensors to operations and data centers via microwave point-to-point links, wireless last-mile standards, and satellite point-to-point links.

Exotic Environments & Peer-to-Peer (P2P) Networking

In exotic environments such as rainforests, deserts, and other technologically remote areas of the world, the capability to transmit data directly to a central server or even to wide-region secondary servers may be hampered by terrain and impermanent access. In these cases, P2P networking is particularly suitable to limit transmission via expensive satellite access. Additionally, the strength of P2P in providing information redundancy is highly appropriate to these higher-risk environments.

There are several concerns that should be addressed when using a P2P system as described above. First, the amount of data being passed between sensors is non-trivial, and constant data exchange can shorten the lifetime of sensor power supplies. To mitigate this fact, P2P arrangements are best paired with on-sensor processing to decrease the amount of information transmitted. Data that is of no interest (which matches a baseline,

¹⁵⁷ Ritchhart, Ken. "Tactical Communications in Border Protection." PowerPoint presentation for the Border Management Summit, Washington, D.C. Customs & Border Protection and Department of Homeland Security. 23 Oct. 2007.

for example, or which marks an absence of seismic/acoustic events) can be discarded or stored locally rather than transmitted among neighboring sensors.

P2P arrangements also bring with them some security concerns. If all data (or all relevant data) is communicated eventually among all sensors, acquisition of only one sensor implies acquisition of all but the latest data. Therefore, strong, key-based, time-variable encryption is desirable when P2P network arrangements are employed.

Analysis & Fusion

The fundamental detection of subsurface air voids cannot be the entirety of our recommendation. Simple accounting puts an operation which monitors the entirety of the U.S. border with Mexico solely with technology at a cost of more than one hundred million dollars per year. While concrete estimates of cost of implementation are outside the scope of this report, it is appropriate to observe that this level of funding is unlikely to become available for this purpose.

To work around funding impediments to implementation of a solution on the border, appropriate fusion of smaller subsets of data with existing channels is not only prudent, but necessary. Several data channels are appropriate to this sort of fusion. Human intelligence – direct observations of law enforcement and security professionals – is one such channel. Additionally, certain indicators of risk as discussed earlier may suggest concentrating sensor and analysis resources in particular areas before there is suspicion of extant tunnels. Further, patterns can be extrapolated from existing law enforcement and civil data sets, including traffic patterns, crime levels, and similar quantitative socioeconomic factors.

The salient point is that fact of the existence of these sets of data and sources of information does not automatically expose them for fusion with tunnel detection sensor data. Appropriate networking and placement of the final data products alongside existing data sets is required, as well as shaping of the data products into a format which is readily fused.

Monitoring & Verification

Given that a communications framework exists, making use of it to provide monitoring of sensors and timely response to returned data is the next difficulty. However, providing this sort of monitoring may not be as difficult as it seems. Monitoring large systems of distributed technology is a problem that is well-solved, particularly in the telecommunications industry. To develop an instructive example, as of the end of 2003, one telecommunications provider in Omaha, Nebraska provided telephone service to approximately 107,000 customers.¹⁵⁸ Using a tiered, node-based system for connectivity to equipment at customer locations, the provider offered continuous monitoring for this customer base, with the capability to see and respond to a variety of equipment alarms – intrusion, loss of communications, loss of power, and a variety of other errors – in real-time. This was accomplished with a monitoring team of only eleven people staffing the operations center 24 hours per day, 365 days per year.¹⁵⁹

Assuming the same number of sensors spread over the western half of the U.S. border with Mexico, a similar level of monitoring could be provided for one sensor every fifteen meters – the width of a standard basketball court. A similar level of monitoring, however, might not be adequate for the data types returned. Additionally, response would be somewhat more limited as the linear distance from a single operations center to a particular sensor would be on average much greater. This increased distance and resultant increase in response time could be mitigated to a large extent by distributing response resources over the length of the border and dispatching them remotely. In short, simple monitoring for alarm conditions, combined with response merged into day-to-day law-enforcement activities may be feasible without exorbitant cost.

¹⁵⁸ Larson, Virgil. “Number of Omaha, Neb.-area phone listings drop.” Omaha World-Herald. 10 Aug. 2004. Online version.

¹⁵⁹ Rees, Robin. Personal interview. 3 Dec. 2007.

Recommendations

With an understanding of the background of the tunneling problem and the constraints on a potential solution set, a series of recommendations can be formed. While the thrust of the following recommendations will be technology based, tunneling is motivated by socioeconomic factors. A full solution to the problem cannot be achieved with technology alone. Therefore, the recommendation that follows is a synthesis of technologies, implementation strategies, and policy proposals.

Technology Combination

Due to the wide variety of circumstances and environments in which tunnel detection and monitoring technologies must be deployed, no individual technology is a perfect fit everywhere, nor is any particular technology appropriately used or deployed at all times. Recognizing the constraints placed upon the use of technologies by both socioeconomic factors and physical realities, use of a combination of technologies is the only prudent course of action. In order to facilitate a recommendation for the specific technologies to be employed, an exploration of the previously mentioned factors and realities will be used to model the area of interest in a survey of both tunnel types and risk levels. Following these models, appropriate technologies will be assigned to various area profiles.

Tunneling Risk Level

When employing any recommended technology the cost and effectiveness must be assessed. For a complete tunnel detection solution to be successful, the necessity and priority of employing a technological solution must also be assessed. Assessing these two factors will effectively lower the cost and time requirements by limiting the area of deployment, as well as the level and amount of technology used in each area. In the specific case of the U.S. continental borders, scanning the entire border is not only cost

prohibitive but also unnecessary.¹⁶⁰ Thus it is logical to create a system which assesses the risk of tunneling along all areas of both the northern and southern borders.

The System - Overview

In order to decide which type of technological solution, if any, should be employed to an area along the border, the associated risk level for that area must first be fully understood. A geographical information system (GIS) can be created to assess this risk level and would continually update the probability of tunneling activity for each square foot along the border. The risk level is computed based on a number of factors, which will be defined in the next section. The important factors should be input into the software program and a geostatistical analysis can overlay a gradient representing tunneling risk. This level will then be constantly updated as the risk level factors change. From this system, decisions can then be made for which type of technology to apply to each area based on a high or low risk level. Figure 15 shows an example output of the GIS software and simple risk level assessment of the California-Mexico border.

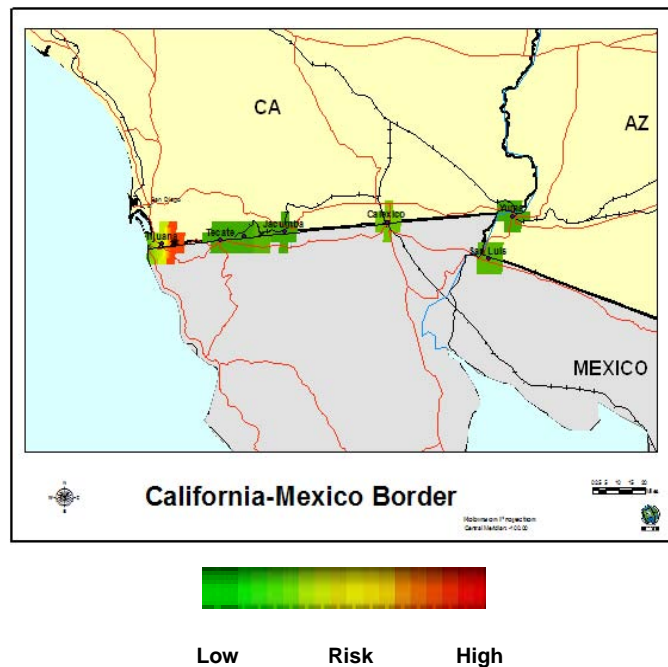


Figure 15: Risk Assessment Output

¹⁶⁰ Symons, Neill, Gregory Elbring, Terry Stalker. Sandia National Laboratories. Personal interview. 25 Oct. 2007.

The risk level color code is shown in the key. The areas with no color would represent areas of effectively no risk, areas of green represent low risk, and red identifies high risk. This system only assessed previous tunneling activity and urban ground cover as weighted factors. The actual proposed system would include numerous other factors and would be far more conclusive. However, this is an approximation which is useful in illustrating the principles at hand.

Factors

Of course, the first step to creating this system is defining the factors which affect the probability of tunneling in an area of interest. This information can be gathered from the areas of existing tunnels and calculating each one's weight on the outcome. Some of these factors may include, distance from the border, depth to water table, soil type and moisture, ground cover type, previous tunneling activity, drug and human trafficking routes, human intelligence, proximity to POE and cities, roads and railroads, terrain, areas of economic development, and subsurface data from sensing devices.¹⁶¹ Of these factors, some are more complex than others and each holds the potential to affect the risk of tunneling in a different manner and magnitude. For example, if the water table is too close to the surface for a person to tunnel above, the chances of tunneling in that area are reduced greatly. However, if there is a greater distance to dig between the surface and water table, it is far more probable that tunneling will occur. The way each factor directly effects tunneling must be analyzed and interpreted numerically and input into the tunneling risk level system in order to accurately calculate the risk.

Analyzing the known data and making such inferences would have to be accomplished by an experienced statistician. The system would be updated and refined as more information is compiled and sensor data is continuously obtained. For example, if the recommended solution eventually deters tunneling in one location and the efforts of the tunnelers was forced to more rural areas, the system could be adapted to this change and subsequently re-assess the risk levels accordingly. The system could also allow the user

¹⁶¹ Symons, Neill, Gregory Elbring, Terry Stalker. Sandia National Laboratories. Personal interview. 25 Oct. 2007.

to drill-down to assess local risk levels and could ideally be incorporated with existing security information systems.

Summary of the Risk Assessment System

The advantages of establishing a risk assessment system includes limiting the range which technology is employed over, determining the investment or cost for each area, and fusing the different forms of data into one centralized location. Obviously it would be very costly and time consuming, as well as unnecessary to employ all technologies across the entire border. Understanding the areas where certain technology does not need to be employed is a major step in resolving these issues. When a location is identified as necessary for a technological solution, the best solution can also be chosen for a particular area. For example, human intelligence may make the risk level rise in one city which was previously had a low risk for technological employment. If this area had no previous tunneling history it is likely to be an isolated incident, not worthy of a permanently embedded seismic array, thus for this case a mobile seismic kit as well as any other applicable technology could be employed. These types of deployment options will be discussed later in the report. The system would also aid in fusing the different forms of data. For example, once the initial risk level is assessed and the recommended level of technology is deployed, the system should be able to merge data from different forms of technology being used and improve the risk assessment level accordingly. Once a certain risk level is met, agents can then invasively probe for the tunnel. The system would not remove the human component in analyzing which technologies should be employed, but rather it would simply aid in this decision. This system could be applicable to both the Canada and Mexico borders or in other areas around the world.

Subsurface Sensing Solutions

Since there is no one silver bullet technology for tunnel detection, it is a problem which must be solved by a combination of detection technologies. Each subsurface imaging and sensing technology better applies to different environmental and geological conditions as well as to different tunnel types. The applicability of each technology is based on a number of situational factors including but not limited to, soil type, human infrastructure, unwanted noise sources, depth to tunneling activity, size of tunnel, and the level of tunnel

sophistication. It is the project team’s recommendation to employ a combination of three different technology based systems. The three selected systems of technology include; permanent seismic sensing arrays, mobile electromagnetic induction sweeps, and a mobile sensing kit, including mobile seismic arrays and ground penetrating radar technologies.

	Seismic and Acoustic	Electromagnetic Induction	Ground Penetrating Radar
Depth	40 ft +	Up to 100 ft	Up to 10 ft
Accuracy	Least amount of false positives/negatives	High amount of false positives	Poor resolution with depth
Fixed or Mobile	Fixed or Mobile	Mobile	Mobile
Cost per unit area covered	High	Low	Low
Soil Preference	Any	Any	Best in dry soils



Figure 16: Recommended Subsurface Sensing Solutions^{162 163 164}

Figure 16 compares the three recommended technologies, identifying each solution’s advantages and disadvantages, in terms of the depth of penetration, accuracy, operation method (fixed or mobile), cost per unit area of coverage, and soil preference. Below each column is an illustration of the appropriate technologies.

¹⁶² “Geophone.” Online Image. 29 Dec. 2007. <<http://www2.informatik.hu-berlin.de/~hochmuth/bvp/geofon.htm>>.

¹⁶³ “Electromagnetic (E.M.).” Online Image. 29 Dec. 2007. <<http://www.geosurvey.co.nz/services.html>>.

¹⁶⁴ “Complete GPR System.” Online Image. 29 Dec. 2007. <<http://www.geophysical.com/WhatIsGPR.htm>>.

Permanent Seismic Sensing

Clearly, based on previous tunneling activity, one can identify that tunneling often recurs in the same areas. Based on this analysis, the highest risk areas occur in urban areas near POE. For these recurring problematic areas, the most effective solution would be a permanent array of seismic sensors. If the tunneling risk assessment system indicated a recurring high risk area, a permanent seismic array would be recommended. Ideally, the seismic array will be able to use both active and passive methods. Since passive seismic sensing has had the most conclusive test results and by far and away produces the least false positives and negatives of any other technologies.¹⁶⁵ The installation must be a permanently embedded, unattended solution, which requires very little physical human data collection.

The primary means of detection for the seismic array will use passive seismic sensing in order to “listen” for subsurface activity while filtering out unwanted noise. This is the most successfully tested method for detecting shallow tunneling activity. It produces the least number of false alarms, yet still has room for improvement in its sensitivity and refinement.¹⁶⁶ An array of these geophone sensors would consist of geophones buried at multiple depths, in order to increase the coverage area and boost the systems ability to discriminate between subsurface tunneling and unwanted noise. Buried sensors also provide the advantage of hiding the technology from tampering and vandalism. The sensors are capable of sending location information of an incoming seismic source. Based on this concept, it is probable that nearby sensors will detect the same activity and the location can be verified. The project team recommends a sophisticated geophone sensor which can isolate three different components of seismic activity as described previously. The level of maturity of passive seismic detection technology is sufficient to merit some form of implementation. A number of experts in the field are already refining implementation methods.

After a permanent seismic array of sensors is installed, active sensing could also be used to image the subsurface, thus reducing costs. Although the imaging capabilities are not

¹⁶⁵ McKenna, Jason R. U.S. Army Corps of Engineers - Engineer Research and Development Center.

¹⁶⁶ McKenna, Jason R. U.S. Army Corps of Engineers - Engineer Research and Development Center.

yet accurate enough to simply image and identify tunnels on its own, active sensing would provide a means for change detection which could help identify or confirm the presence of a tunnel. A number of the inadequacies which active seismic imaging presents can be improved and resolved with more R&D. Active imaging would take place on a necessary basis, possibly every month, quarter, or twice a year. Active sensing would require a seismic source be operated along the array and would be most effective during times of lowest levels of unwanted noise, i.e. at night with the road closed. Since this would only have to be performed a few times per year, it would not burden those performing the active test. The operators would only have to run the signal source along the border and data would still be sent to the data analysis center for processing, in the same way as passive sensing. As long as the buried geophone sensors' sampling rate is set at an adequate speed, active sensing will be possible using the same geophones as passive sensing. Passive seismic sensing does not require such a high sampling rate, because it does not rely on rapidly moving wave reflections from a known seismic source. Therefore, if absolutely necessary for more efficient data transmission sizes the sampling rate of each sensor may need to be adjusted to accommodate the two different seismic methods.

Mobile Electromagnetic Induction

A major component of the technological recommendation is mobile electromagnetic induction. There are two known companies which make the recommended units, namely Argus and Stolar. Both models sense differently, yet are based on the same principle of electromagnetics. Each is better at detecting different sensing situations and provides a unique applicability to the recommendation; the Stolar model senses improved tunnels more accurately and the Argus EM3 provides more applicability in detecting shallow unimproved tunnels.¹⁶⁷ It is the project team's recommendation that these mobile units will be used in all areas which are defined as having a high risk of tunneling; this includes the high risk urban areas as well as low-risk rural locations which still have some risk associated. Although the technologies can be useful for a simple scan and detection method, they produce too many false positives to be trusted as a stand-alone

¹⁶⁷ Parkman, Kevin. Personal interview. 5 Nov, 2007.

solution.¹⁶⁸ However their readings are more useful for change detection methods. Therefore, large areas of interest could be scanned for comparison with future data. It is the project team's recommendation to take a baseline reading for as much of the border as possible, with the major limitation of being able to cross difficult terrain. This baseline EM reading will ultimately be useful for change detection as new tunneling activity occurs.

Mobile Sensing Kit

The third recommended technology system is a mobile sensing kit. This kit would be applied in situations when a location is identified as high risk, but is likely to be a more isolated incident, than those which would be candidates for a permanent seismic grid. For example, the kit may be applied between two cross-border rural houses suspected of tunneling, rather than directly along the border in the most frequently tunneled cites. It would contain a mobile seismic setup with as many geophones as necessary; it could also include a GPR solution for locations where the suspected tunnel uses the road for its ceiling. For example, if a road has sunk in, a team could operate the mobile kit to gather more conclusive data for analysis. In this manner, this kit allows the conclusive testing of any area, given that a team can have access to temporarily installing/operating some equipment local to the area of interest. In conclusion, this kit is used to verify a tunnel's existence if the other technologies or the risk level assessment deem the area high risk and as long as the equipment can be operated in the area of interest.

¹⁶⁸ McKenna, Jason R., Robert Horton, Gregory Elbring, Amy Clymer, and Clifford Hansen. "Tunnel Detection Technology Demonstrations: Otay Mesa and Calexico, California." U.S. Army Corps of Engineers - Engineer Research and Development Center. Dec. 2006.

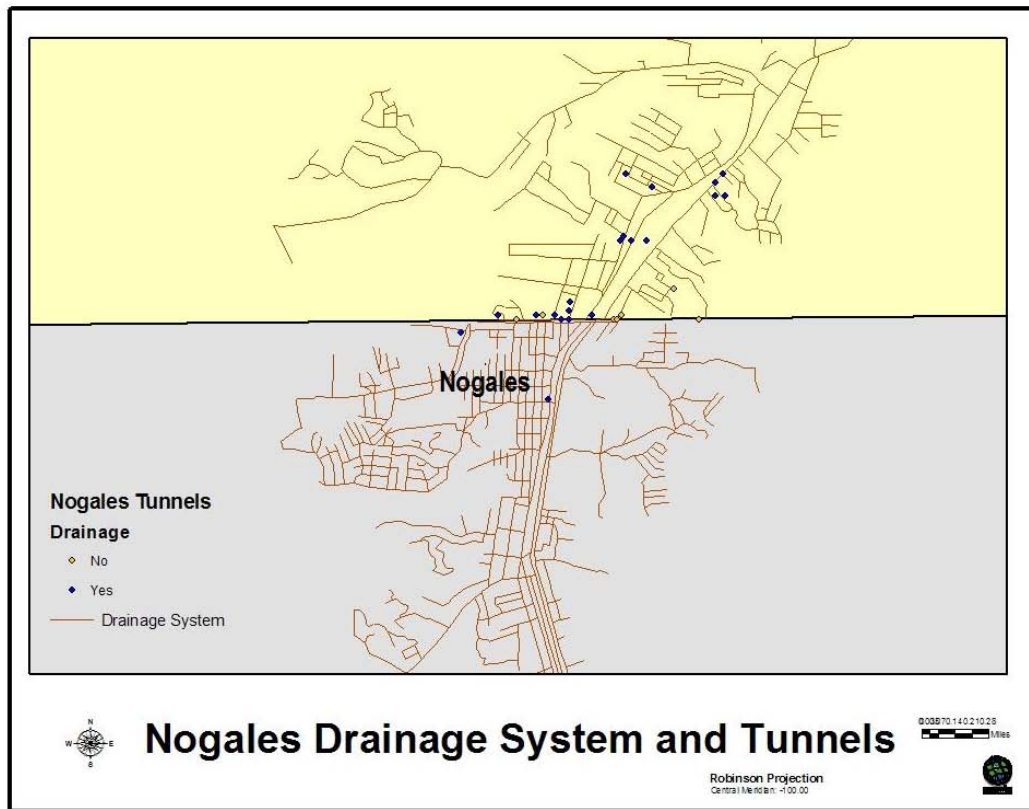


Figure 17: Nogales Drainage System

Motion Sensing Solutions

Based on this historic tunneling problem in Nogales, Arizona, and El Paso, Texas, there is a significant need to monitor the drainage system for human activity (See Figure 17). For this issue the project team recommends the installation of a motion detection system into the drainage system, utilizing a combination of motion sensing technologies.

When analyzing a solution for motion detection there are a few main concerns which must be addressed. The solution must be fixed, waterproof, concealed, and completely self sustaining. Meeting these requirements is by no means impractical many of these technologies are commercially available. In fact waterproof motion detectors can already be purchased. However they are not usually built for such a strenuous environment as exists in the drainage systems. Therefore, a special motion detector combined with an infrared, or heat, detector would have to be designed for use in the sewer or drainage systems, but would still be fairly cheap since the technology already exists. Once employed, these sensors will monitor for human activity in the drainage systems and

report the information back wirelessly whenever an intrusion occurs. The info can be acted upon as appropriate and will actually allow the illegal activity to be caught while inside the tunnel. The combinational sensors are capable of discriminating against smaller intruders such as animals and it could provide the best discrimination against possible false alarms. Two additional challenges persist. First, each unit must be powered by a hydroelectric or traditional wired source. Second, the sensors must be concealed so they are not stolen or destroyed.

Recommended Deployment Strategy

As discussed above, the recommended deployment strategy was selected based on the tunneling risk level, cost, surveillance area, and adaptability. Due to the existence of both high-risk and low-risk levels of tunneling activity along the southern United States border, a different deployment strategy for each risk assessment was developed. The finalized deployment strategy is shown in the table below:

	High Risk	Low Risk
EM Gradiometry	Manned/ATV	UGV
Seismic Sensors	Permanent Array	Mobile Sensor
GPR	Manned/ATV (infrequent)	No Use

Table 2: Recommended Deployment Strategy

As demonstrated by Table 2, the operation of the tunnel detection technologies will be a combination of manned operations and autonomous systems. Both columns of the table (High Risk and Low Risk) will be discussed in the following sections.

High Risk

Areas identified by the tunneling risk assessment as having a high risk of tunneling activity will see a much higher presence of technology than the low risk areas. It is important to note that all high risk areas identified by the preliminary risk assessment are located in urban environments, which affected the operational recommendations for the three technologies.

The EM gradiometers will be deployed via manned operations, transported by All Terrain Vehicles (ATVs). By utilizing the ATVs, mobile scans of the high risk areas could be completed in a relatively short amount of time. The decision to implement manned operations of the EM gradiometers was made due to the presence of the population and increased traffic found in urban environments. Such conditions would hamper the operation of a semi-autonomous Unmanned Ground Vehicle (UGV).

Assuming that the current high-risk areas remain high-risk for an extended period of time warrants the installation of a permanent seismic sensor array. Installation of such a system could be easily achieved, as the existing infrastructure of an urban environment would provide ready access to power and communications capabilities. The installed sensor array can be operated as a passive or active system, as the situation dictates. A permanent sensor array is capable of covering a large area, which was previously discussed.

The use of ground penetrating radar has shown promise in the field of tunnel detection, although the results from testing have been somewhat inconsistent. However, GPR has shown significant strength when detecting voids beneath concrete or asphalt. Therefore, the recommended deployment strategy includes the use of manned GPR operations, also transported via ATV. However, the operation and scanning performed by GPR will be performed infrequently, due to the inherent risk of operating on city streets and highways.

Low Risk

The areas on the exterior of the urbanized locations along the southern United States border have preliminarily been identified as having a low risk of tunneling activity. Therefore, the high volume of technology recommended for the high-risk areas would not be feasible for use in the low-risk areas.

Due to the lowered presence of traffic and the low population of the low-risk areas, EM gradiometer operation via UGVs is recommended. By utilizing a UGV capable of automatic waypoint transportation via GPS, the operation of the technology could be nearly autonomous. This system greatly reduces the amount of manpower needed to scan the border, while allowing full scans to be completed quickly. It is recommended that

several of these UGVs be employed along the border to quickly acquire a baseline scan of the low-risk areas.

When a target area is identified by the EM gradiometers, a mobile seismic sensor unit should be deployed to further analyze the potential tunnel location. The mobile sensor unit would be operated by a one or two man team in the field. The use of this mobile sensor unit would allow government officials to quickly verify the location of a suspected tunnel. By applying this tiered system of tunnel detection to the low-risk areas, the border could be effectively scanned for tunnels while maintaining a minimum amount of personnel required for the operation.

Due to the inconsistent testing results and the amount of time required for operation and data analysis, ground penetrating radar is not recommend for use in the low-risk areas of the southern United States border.

By implementing this double deployment strategy approach, the border can be sufficiently managed by a minimum amount of personnel for a reasonable cost. To meet the final consideration of the deployment strategy selection, adaptation, it is estimated that should tunneling operations spread from the high-risk areas to the lower-risk areas, the high-risk deployment strategy could quickly be implemented into the previously low-risk areas of the border. This transition would be assisted by the fact that aside from the permanently installed sensor array, all other recommended technology deployment platforms are mobile. By purchasing and installing a relatively small amount of additional sensors and equipment, the high-risk surveillance area can be expanded at a rapid rate. With a system already in place, the training and deployment of additional personnel could be handled in an efficient and expedient manner.

Additional Deployment Methods Not Recommended

Unmanned Aerial Vehicles (UAVs) were considered for transportation of EM gradiometers for the purpose of quickly scanning the border's low-risk areas. This method seemed feasible, as the U.S. Border Patrol currently operates two UAVs along the southern United States border. However, it was determined that the maximum speed that the EM gradiometer can travel and still collect data useful for tunnel detection was

approximately five miles per hour. Unfortunately, this is well below the cruising speed of an Unmanned Aerial Vehicle.

The use of a satellite communication network for the permanently-installed seismic sensor array was considered. However, this method was not recommended as the price of data transmission over a satellite network was exponentially larger than the cost of transmission over a local wireless network.

Implementation

Since each of the three technologies has room for improvements, time should be allowed for some to be developed further. Thus, implementation of the recommendations previously described could be employed in two major phases with first phase involving basic testing before a full border rollout would take place. This will allow R&D efforts to refine the technologies and improve the performance of each.

Phase 1

The first phase (1-3 years) of implementation requires utilizing a completed version of the tunneling risk assessment system. All three technology options can then be employed by experts and tested during this phase. Once the risk levels have been analyzed, an area of focus can be pinpointed as most likely for recurring tunneling activity. This area of highest probability will be selected for an implementation of the fixed seismic array. An ideal situation is if this location were to include an area over an existing tunnel so testing can be performed that does not require new tunneling activity. At the same time, the technologies can monitor for new tunneling activity and movement in current tunnels which were previously unidentified. San Diego is an ideal location that meets these criteria. Additionally, San Diego's Tunnel Task Force Team has proven to be very effective at multi-agency cooperation which may help the ease of integration of the recommended technologies. Ultimately, the testing phase needs to verify that the tunnel void identified by the sensors is actually a tunnel and acquired information is precise enough for positive verification. The sensor data can be processed at the respective data analysis center and the risk assessment system can effectively "learn" to filter out more site specific, unwanted noise. With the seismic array in place active readings can be

taken, data is analyzed, more advanced analysis techniques can be developed, and this data is later used for change detection.

Electromagnetic induction sweeps can begin during this phase by utilizing the recommended EM units and a baseline survey can be conducted in areas of interest. This will most likely include a large portion of the southern border except for Texas because of the Rio Grande. The data can be taken in lines parallel to the border at varying distances, to better discriminate against false positives. This data will then be input into the tunnel risk assessment system and improve the risk assessment model. Based on the incoming EM data and other factors, a mobile kit could then be employed to further analyze high-risk areas.

In summary, the most critical part of phase 1 is the initialization of research and development on the technologies recommended in the test area or pilot program area. Testing is necessary for continual enhancements to current, fixed technology. The types of sensors and the way they transmit data should not change but the major improvements will come in data analysis and verification. This will be an ongoing effort until the testing phase is complete and the results are satisfactory, at which point a phase 2 implementation can be implemented.

Phase 2

The second phase would be an unrestricted full border deployment of technology along the border with areas of high or low risk. Each long-term high risk area can be considered for a permanent array of seismic sensors and more gradiometer sweeps can be performed using the improved technology, across a larger area of the border. Although R&D is an ongoing effort, this would be a point which the technologies performance would be satisfactory in securing the borders from the threat of tunneling. After permanent sensors have been installed in urban or other high risk areas and data is being collected from the sensors in real-time, information will be sent to USBP command and control centers which will store and analyze the data. This data will be fed back into the risk assessment system and the risk levels will change accordingly. Border Patrol agents will then be trained to operate the mobile sensors. The result of this phase should be a major crackdown on the areas of high risk, i.e. cross border cities, while maintaining a baseline

of the less risky areas for future comparison, thus securing them from a resulting shift in the location of tunneling to more rural areas.

Political, Military, Economic, Social, Information, and Infrastructure (PMESII) Support for Recommended Technologies

Since there is no silver bullet or any one technological solution for all areas susceptible to tunneling, the U.S. needs a proactive and holistic approach to tunnel detection. Currently, no tunnels have been found using technology, and DHS believes there are still numerous tunnels along the U.S. borders that have yet to be discovered.

Once the recommended border baseline survey has been completed, tunnel detection mobile sweeps are taking place, and permanent sensors are being used, tunnel detection along the U.S. borders will become proactive instead of passive. The technology recommendations and continued R&D are vital to deterring tunneling activities, and moreover, are critical to comprehensive border security. Still, for tunnel detection technologies to be successful, effective policies must also be implemented and maintained to support tunnel detection efforts.

A compliment to the recommended tunnel detection technologies is the following PMESII recommendations.

Political

In order to be successful any tunnel technology recommendation requires political support. For this to happen, more communication is needed, both within U.S. political circles and with the governments of Canada and Mexico. Within the U.S., meetings should be occurring at federal levels. First, a coalition of border states would function to allow governors from the nine border states to meet to discuss border security issues. Second, this same coalition could meet with officials from both the Mexican states and the Canadian provinces to develop cross-border strategies.¹⁶⁹ Multilateral meetings will encourage trust, cooperation, and understanding between all countries.

¹⁶⁹ Benjamin-Alvarado, Jonathan. University of Nebraska at Omaha Associate Professor of Political Science. Personal interview. 14 Nov. 2007.

Additionally, the federal agencies in areas with a high probability for tunneling along both borders need to be brought together and cooperative. Currently, some single-agency tunnel task forces exist within ICE, the Nogales Border Patrol, and the El Paso Border Patrol. A multi-agency San Diego Tunnel Task Force team has been rumored to be the most effective defense in coordinating and prioritizing efforts to locate, investigate, and prevent border tunnels. While San Diego has admitted that cooperation could end at any point, it would be most beneficial to make multi-agency tunneling task forces a permanent standard for all areas along the border susceptible to tunneling. Like the San Diego Tunnel Task Force team, the DEA, ICE, and CBP could be integrated in other cities under the banner of counter-tunneling.

Thirdly, Border Patrol could meet in a sector by sector basis to increase communication along the borders. Each sector would be updated on intelligence as tunnel technology produced significant results that needed to be further investigated. With cooperation formalized, information leading to tunnel detection will be disseminated more quickly and communication will raise awareness of new issues. Other agencies with a vested interest in border security, specifically tunnel detection, would be welcome to participate in these meetings. These formalized groups would additionally have positive impacts on other facets of border security and ensure that tunnel detection technologies and implementation strategies are shared.

In areas where these Tunnel Task Forces are created the Border Patrol agents could be trained to use applicable tunnel detection technology. The initial training is recommended to be directed towards the upper enlisted agents. This training will more than likely be provided by technology experts, but following the training regimen, the upper enlisted will be qualified to both operate the equipment and train other agents on its usage. Training should take place at the Border Patrol Academy in Artesia, NM, or at other sites where technologies are being implemented or tested.¹⁷⁰ Additional training will be needed for specialized sensors in El Paso and Nogales in the drainage and sewer systems, most likely onsite.

¹⁷⁰ United States. U.S. Customs and Border Protection. Border Patrol Agent. Washington, D.C.: United States Border Patrol. Apr. 2006.

This program would quickly form a force of agents qualified to operate the tunnel detection equipment that are also qualified to handle all other aspects of the U.S. Border Patrol mission set. Concurrent with the implementation of a full training regimen, the development of the appropriate field manuals will also have to be addressed. One field manual could be written for each of the recommended technologies. The writing of these field manuals should be advised by the current experts in the field of tunnel detection technology.

A few select agents in each Border Patrol sector's command and control center should also be trained by experts to analyze the sensor data once a sensor fusion and geographical information system has been set up. When a tunnel has been located, an alert will be posted on JTF-North's secure web server (discussed in the following Information section). All appropriate agencies will then be notified and appropriate actions can take place.

Legislation and Agreements

Congress should pass the House of Representatives' bill H.R. 3916, which would require DHS to outline manpower, training, and operations and maintenance costs for research activities. This bill requires that specific tunnel detection technologies, including both mobile units and permanent sensors, and data processing and operational costs be included in budget requests so the entire tunnel detection program can be funded as soon as it is ready to be deployed.¹⁷¹ An outline of these costs is a necessity for an effective program.

Since no legislation currently exists specifically for tunnel prevention in Canada or Mexico, the U.S. should conduct negotiations with the two countries to, at a minimum; arrive at MOUs and MOAs regarding illegal border activities, tunnel construction, and tunnel remediation. MOAs already exist within the CBP regarding construction of border

¹⁷¹ United States. Cong. House. 110th Congress, 1st Session. H.R. 3916, A Bill to Provide for the Next Generation of Border and Maritime Security Technologies [introduced in the U.S. House; 22 Oct 2007]. 110th Congress. Congressional Bills, www.thomas.gov access. 11 Dec. 2007

fencing, so tunnel MOUs or MOAs can be modeled after these.¹⁷² Some major topics of consideration are international agreements, interagency cooperation, tunnel remediation procedures, and law enforcement investigations. These agreements must not only be written, but also be acted upon and updated, as necessary.

Jurisdictional Issues

When operating mobile tunnel detection equipment or installing permanent sensors, Native American tribes, National Wildlife Refuges and Monuments, and other areas must be worked with on a case-by-case basis to determine the best approach of action for tunnel detection. Since the Tohono O’odham Reservation is located in the Sonoran Desert and is thus classified as low-risk for tunneling, only a baseline survey will likely take place here. Several other laws, regulations, permits, and licenses must also be complied with when conducting tunnel detection operations along the border, such as the National Environmental Policy Act, Archeological Resources Protection Act, National Wildlife Refuge System Administration Act, Migratory Bird Treaty Act, and many other federal, state, and local regulations.¹⁷³

Canada

In the short-term, the U.S. and leaders of the RCMP and the CBSA could identify high-risk areas for tunnels along the U.S.-Canadian border, like new housing and commercial developments in British Columbia, and discuss a plan of action for tunnel detection. IBET teams should be created soon along the whole border and these should focus on better information sharing and interagency training. MOUs and MOAs can also be created and acted upon for tunnel detection, investigations, and remediation.

In the long-term, Canada can work on enforcing its asylum, terrorism, border security, and drug laws. Asylum laws have recently been revised with improvements regarding the harboring of terrorists, but many effects of these have not yet been realized. Therefore,

¹⁷² United States. Congressional Research Service. Border Security: Barriers Along the U.S. International Border. Blas Nunez-Neto and Stephen Vina. Washington, D.C.: Library of Congress, 2006. 12 Dec. 2006. CRS Web. 12 Dec. 2007 <<http://www.fas.org/sgp/crs/homsec/RL33659.pdf>>.

¹⁷³ CBP - SBInet Program Management Office. “List of Laws, Rules, Regulations, Processes, Permits, Licenses, Reviews and Approvals that Could Apply to SBInet Task Order Projects.” Excel spreadsheet. 30 Aug. 2007.

the U.S. should enter into talks with Canada about the importance of overall enhanced security, both at borders with the U.S. and internally.

Reform could also be negotiated regarding drug policy since a large amount of drug traffic occurs along the U.S. – Canadian border and Canadian laws are more lax than those in the U.S. Measures have already been taken by Prime Minister Stephen Harper in 2007 to enforce “mandatory prison terms for serious drug crimes as part of a \$63.8-million, two-year drug strategy he says will offer help to addicts and punishment to dealers.”¹⁷⁴ The U.S. should stress that these initiatives will be beneficial for the security of Canada, while keeping the borders open for legitimate bi-national trade and travel.

Mexico

In the short term, Mexico needs assistance achieving the rule of law, particularly regarding enforcement of drug, terrorism, weapons, and human smuggling laws. Multi-lateral cooperation with the U.S. and other nations would help; instead of making security with Mexico a bi-lateral issue, the issue of security could be given the attention of Mexico and the world.¹⁷⁵ As an example of the success of this approach, one can look to security changes Mexico has made along its southern border with Guatemala. The approach to this issue – placing Mexico in the role of potential solution, rather than the problem – guided its success. Mexico reached out to neighboring countries and received successful security advice citing the need for change, rather than a judgment of Mexico’s standing security policies. Generally, bi-lateral talks between the U.S. and Mexico have led to internal critiques instead of positive advice. Advice and assistance are most likely to be well-received if Mexico is to be both the guiding hand behind, and the beneficiary of positive results.

Another short term goal for Mexico is to create teams similar to the IBETs of Canada along each Border Patrol sector, possibly incorporating Border Patrol Mexican Liaison

¹⁷⁴ “Canada Moves Toward Reform of Drug Policies.” 2007. Common Sense for Drug Policy. 28 Dec. 2007 <<http://www.csdp.org/news/news/canada.htm>>.

¹⁷⁵ Benjamin-Alvarado, Jonathan. University of Nebraska at Omaha Associate Professor of Political Science. Personal interview. 14 Nov. 2007.

Units (MLUs) into this new initiative.¹⁷⁶ IBETs should be created to include Mexican officials representing a variety of federal agencies including, but not limited to, Grupo Beta and PFP. The new U.S.-Mexican IBETs would cooperate on law enforcement procedures, relevant information sharing and investigations, and tunnel remediation. Border cities should continue to hold border safety conferences and discuss tunnel issues, as necessary.

Military

As DHS goes forward to fund R&D for tunnel detection technology, it is essential to include DoD because the technology that is developed may have applications for DoD operations outside of the U.S. as well as domestically. The previously mentioned bill, H.R. 3916, would ensure increased cooperation between these two agencies. Additionally, this cooperation also has implications for shared funding responsibilities.

Economics

The U.S. can assist Mexico in helping to engineer and establish a better functioning economy in the long term. Two areas for immediate economic improvement in Mexico are in the agriculture, and information technology (IT), and education.

The U.S. could potentially provide foreign assistance funding to help sustain the cost of development since Mexico's agriculture infrastructure is not as up-to-date as other countries. Since NAFTA was passed, agricultural subsidies in many countries, including the U.S., have not declined, thus putting many Mexican farmers out of business. Several organizations and lawmakers are suggesting that the U.S., Canada, and Mexico revisit NAFTA or at least help create more jobs in Mexico so people can make a living and less people will enter illicit "underground" economy activities.¹⁷⁷ By reducing U.S. agricultural subsidies, more Mexican farmers who were put out of business by low commodity prices can reenter the farming sector.

¹⁷⁶ United States. Congress. Senate. Committee on the Judiciary. Subcommittee on Immigration, Border Security, and Citizenship and Subcommittee on Terrorism, Technology, and Homeland Security. Statement on Border Enforcement and Technology Between the Ports of Entry, United States Senate, 109th Cong., 1st sess., April 28, 2005. <http://kyl.senate.gov/legis_center/subdocs/042805_aguilar.pdf>.

¹⁷⁷ Suarez-Mier, Manuel. "A View From the South." *Foreign Service Journal* (Oct. 2007): 17-22.

In addition, the U.S. economy is very dependent on foreign workers. In fact, illegal immigrants make up five percent of the U.S. workforce and constitute ten to twelve percent of the low-skilled labor force. If all of these workers were deported, consumer prices would increase in industries like agriculture, maintenance, construction, food preparation, and others. Therefore, a comprehensive immigration program with a temporary worker visa program should be passed to acknowledge the fact that we need immigrant labor from Mexico for our economy to be efficient and healthy.

The U.S. should also encourage and lead private investment in Mexico to spur economic development in IT, service sectors, and other high-impact industries. U.S. companies should consider Mexico as a source for employees for thousands of outsourced IT jobs. Unfortunately, underemployment of professionals in Mexico creates a disincentive to specialize. Creating incentives for those companies to invest in IT operational centers in Mexico could help alleviate this problem. The U.S. should also encourage and facilitate exchange programs for Canadian and Mexican students to study in the U.S., learn entrepreneurial skills, and provide microfinance loans to them to start new businesses.¹⁷⁸ These initiatives can help provide more opportunities for Mexican workers so they do not partake in the “underground” economy which takes place in tunnels.

Funding

For an effective tunnel detection project, future DHS budget submissions should include estimated costs for tunnel research and development projects, in addition to costs for additional law enforcement, staffing requirements, data fusion and analysis, information systems integration, and administrative costs. R&D for successful tunnel detection technologies project could require \$100 million over three to five years,¹⁷⁹ but this funding could be divided between DHS and DoD’s budget requests because some of the technological advances would be used both domestically and abroad. A memorandum was signed by Attorney General Janet Reno and Deputy Assistant Secretary of Defense John Deutsch in 1994 that authorized “advanced technologies and systems” to be

¹⁷⁸ Benjamin-Alvarado, Jonathan. University of Nebraska at Omaha Associate Professor of Political Science. Personal interview. 14 Nov. 2007.

¹⁷⁹ McKenna, Jason R. U.S. Army Corps of Engineers - Engineer Research and Development Center.

developed for both military and law enforcement tasks, so DHS and DoD can share technological improvements and R&D costs.¹⁸⁰ The “training and technology used to hunt tunnels along the Mexican and Canadian borders has immediate applications in Southwest Asia [and the Middle East],” commented Army Lt. Col. Steve Baker, the chief of tunnel detection operations at JTF North. Ground forces in these areas are attempting “to root out Taliban holdouts in caves in Afghanistan’s mountains.”¹⁸¹

The funding should be set aside before project contracts are awarded to assure that R&D is not stalled by slow appropriations processes. The turnaround time for proposals, like the BAA, should be submitted and contracts should be awarded within the next year. Awards should range in dollar amounts, but organizations whose technologies have a better probability of future detection technology applicability should be prioritized and awarded higher amounts for a longer term contract. Appropriate accountability and reporting procedures should be in place to assure appropriations are spent effectively, provide positive returns on investment, and are funded in the future. Efforts should be made to ensure that research is not repeated and technology is not reinvented.

In FY07, the Homeland Security Appropriations bill allocated \$5.2 billion for the Secure Border Initiative, \$4.2 billion for ICE, \$2.27 for USBP, among others, but no funding was allocated for tunnel detection. Pending project readiness, tunnel detection should be allocated funding via an appropriations bill.¹⁸²

Social

Laws prohibiting construction, financing, and use of illegal border tunnels are not sufficient to deter criminal organizations nor possible terrorists or WMD from penetrating the U.S. through tunnels. If stronger laws are enacted to punish those who are involved in illegal border tunnel activities, criminals and drug smuggling organizations

¹⁸⁰ Andreas, Peter and Richard Price. “From War Fighting to Crime Fighting: Transforming the American National Security State.” *International Studies Review* (Fall 2001): 31-52.

¹⁸¹ Magnuson, Stew. “Hunters Unearth Smuggling Tunnels.” *National Defense* Jul. 2006. 29 Nov. 2007 <<http://www.nationaldefensemagazine.org/issues/2006/july/HuntersUnearth.htm>>.

¹⁸² McCaul, Michael T. House Committee on Homeland Security. *A Line in the Sand: Confronting the Threat at the Southwest Border*. 27 Aug. 2007 <<http://www.house.gov/mccaul/pdf/Investigaions-Border-Report.pdf>>.

will find other avenues to transport drugs or illegal aliens. A comprehensive immigration and border security package must be implemented to deter these illegal border tunnel activities. As Rep. David Dreier from California stated in the Congressional record on September 21, 2006 before the DHS Appropriations Act was passed, “Using manpower and technology to find these tunnels and shut them down will not stop others from being built and used. Tunneling will only begin to subside after tough and clear penalties are enacted for anyone involved in this pernicious violation of our border and our sovereignty.” It is questionable whether the increased border security, particularly fencing, has caused illicit activity to move underground.

While speaking recently with an immigration expert, Dr. Benjamin-Alvarado, he expressed views about approaches to the problem of illegal immigration and drug trafficking. He suggests that finding a tunnel detection method is chasing an artifact of the greater situation – failing immigration policy and drug policy. Thus, the motivations for tunnel construction must be addressed on a federal level. Like other issues concerning U.S. policy, Benjamin-Alvarado states that immigration policy has morphed into the Immigration Industrial Complex. Instead of creating a real assessment of the issue, the U.S. has broken the issue into aspects of the consequences and is throwing resources at the problem. But this only creates short term solutions. In Benjamin-Alvarado’s words:

From 1986 to 2006 Border Patrol has tripled its agents and man hours, the budget for border control has increased ten-fold, all while immigration doubled. Anyone can see that is a failed policy.¹⁸³

Unfortunately, there is no cure-all for either U.S. drug or immigration policy; however, it is almost instinctive to recommend increasing the number of temporary worker visas issued as well as reviewing drug policy. Labor demand in U.S. must be recognized and adjusted to in order to begin curbing unauthorized migrants from crossing the border illegally. In particular, temporary worker visas could be increased in order to meet the U.S. demand for labor. Also, the U.S. approach to drug control should switch from a supply approach to a demand approach. The U.S. is the world’s largest consumer market

¹⁸³ Benjamin-Alvarado, Jonathan. University of Nebraska at Omaha Associate Professor of Political Science. Personal interview. 14 Nov. 2007.

for illegal narcotics. Other countries rely on this demand to make a living. Currently, the U.S. policy is focusing on a failed supply-side approach. A change in this focus, a demand side approach, would likely decrease the demand for drug trafficking and likely clandestine tunnels used to traffic drugs. These measures would produce a relaxed demand for illegal workers and drugs, and by extension, clandestine tunnels.

Information

Information support is one of the areas which has the potential for large impact on the problem of tunnel detection. Tunnel detection efforts benefit from increased public involvement in information gathering and agency cooperation, and may also see improvement with specific oversight and dedicated data handling resources.

Public Information and Human Intelligence

Since no border tunnels have been found firsthand by tunnel detection technologies, it is important that at least in the short-term, the U.S. citizens are informed about how to report suspicious activities. Public informants would be beneficial when reporting possible tunnel activities in or near their places of work or residency. For example, the tunnel near Lynden, WA, was discovered by agents and residents witnessing dirt coming out and lumber going in to the home where the tunnel entrance was located.¹⁸⁴ The public must be able to report illegal activities at any time of day. Toll-free numbers for each Tunnel Task Force should be available to the public, as well as website forms to report suspicious activities regarding underground passageways.

Agency Cooperation

Local and state agencies, tribal leaders, and leaders of national forests and wildlife refuges, among others, should be brought into the discussion of plans to conduct tunnel detection operations along the border. This should take place during the beginning stages of planning so all policies are compliment each other and to make sure the tunnel detection operations are not harmful to land or create other unintended consequences. Border security should always come first, so if a tunnel is reportedly being built on other

¹⁸⁴ Frieden, Terry. "Drug tunnel found under Canada border." 22 July 2005. CNN Cable News Network. 12 Dec. 2007 <<http://www.cnn.com/2005/US/07/21/border.tunnel/index.html>>.

lands, agency cooperation should take place with the respective leaders. Tribal lands and other special circumstance areas along the border, for example in Arizona, the Barry M. Goldwater Bombing Range, Cabeza National Wildlife Refuge, or Organ Pipe Cactus National Monument, must be considered when conducting a tunnel detection baseline survey. The tunnel detection technology recommendation does not call for any permanent detection technology to be placed in these areas at this time; however, these groups should still be included in relevant discussions, particularly before the recommended technologies are deployed.

Oversight Committee

A tunnel detection oversight committee should be established to address tunnel detection efforts. The committee's members would work together and meet at least twice a year; this committee would be made up of two committees on a lower level. The first committee would be made up of domestic officials from both operational and investigative organizations including USNORTHCOM, JTF-North, DHS, ICE, CBP, USBP, BORFIC, HIDTA, and DEA, among others. A separate technology research team would be composed of officials interested in overseas tunnel detection efforts, including USACE, DARPA, NGA, DTRA, USCENTCOM, and the Tunnel Detection Technical Support Working Group (TSWG). These committees would serve to share technologies that are applicable to domestic and overseas environments. The domestic team should meet at least twice a year to discuss agreements with Mexico and Canada on cross-border tunnels, new technology implementations, new training or staffing needs for Tunnel Task Forces, enhanced interagency information sharing, better data fusion and integration of information systems, new threats, and corresponding national security issues. The overseas team will function to ensure that duplicated research is not taking place, all organizations are working together, and the best tunnel detection program (both domestic and international) is implemented. These two main committees will report to the National Research Council, as H.R. 3916 would require, if it is passed; they would report on the readiness of certain technologies and implications about how the entire system would be

implemented.¹⁸⁵ These agencies should also continue to hold tunnel conferences to provide updates about recent technological and operational developments and to develop strategies to combat challenges.

The Center for the Analysis of Subsurface Activity (CASA) is already functioning as the organization to collaborate efforts of industry, academia, and federal agencies regarding tunnel detection. The Center combines stakeholder's requirements and transition needs with a multi-agency R&D task force. This organization could also serve as the national oversight committee because its members are involved in current projects on both a national and international scope, for example 4D force protection, sensor and environmental interactions, sensor array design, algorithm development, baseline surveys, training users of equipment, and performing data collection and fusion.¹⁸⁶

Central Tunnel Data Collection Site

A central clearing house for tunnel detection technologies in the U.S. should be within JTF-North. Funding should be allocated to allow them to store data on new tunnel occurrences; this information will come from USBP command and control centers along the border or other investigative agencies. JTF-North should also house information on historic occurrences of tunneling, proceedings on tunnel conferences, technologies that either have or have not worked, and technologies that need additional R&D. Involved agencies should have access to this data when needed. All tunnel data should be stored on a secure web server with access usernames and passwords. This will promote information sharing, will make R&D on tunnel detection technology more efficient, and will speed up processes starting with tunnel identification and ending with closure.

¹⁸⁵ United States. Cong. House. 109th Congress, 2nd Session. Department of Homeland Security Appropriations Bill, 2007 [introduced in the U.S. House; 15 May 2006]. 109th Congress. Congressional Bills, GPO Access. 12 Dec. 2007

<http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_reports&docid=f:hr476.109.pdf>.

¹⁸⁶ McKenna, Jason R. "ERDC Tunnel Detection Support to NORTHCOM/CENTCOM." PowerPoint Presentation for the BORFIC/JTF-N Border Tunnel Conference. U.S. Army Corps of Engineers - Engineer Research and Development Center. 7 Aug. 2007.

Information systems should be developed that can analyze relevant parts of sensor and geographic data, model of near-surface phenomenology, and interoperate with existing border security systems, including SBInet after it is operational.¹⁸⁷

Infrastructure – Border Fencing

If more border fencing is to be built in the U.S., clandestine actors are likely to be temporarily discouraged, but eventually move operations around, under, or over the fence. The existence of fencing actually impedes efforts of certain tunnel detection technologies; EM gradiometry readings, for example, are skewed by the existence of metal fencing.

Additional fencing efforts should take environmental and fiscal costs into consideration. After San Diego's primary fence was erected, unauthorized aliens and smugglers simply began to move through environmentally sensitive areas and lawmakers later realized that a "rigid" enforcement system is needed with integration from personnel, technologies, and a multi-tiered fence. Also, as San Diego sector apprehensions declined from over 550,000 in 1992 to just over 100,000 in 2004, illegal immigrants simply moved to the Tucson Border Patrol sector as they saw roughly a 85% increase in this region during the same time period.¹⁸⁸ The following Figure 18 shows the same results in FY 2006 and 2007.

¹⁸⁷ Dizard, Wilson P, III. "DHS seeks 'tunnel vision'." 20 Feb 2007. Government Computer News. 12 Dec. 2007 <http://www.gcn.com/online/vol1_no1/43182-1.html?topic=it_management>.

¹⁸⁸ United States. Congressional Research Service. Border Security: Barriers Along the U.S. International Border. Blas Nunez-Neto and Stephen Vina. Washington, D.C.: Library of Congress, 2006. 12 Dec. 2006. CRS Web. 12 Dec. 2007 <<http://www.fas.org/sgp/crs/homesecc/RL33659.pdf>>.

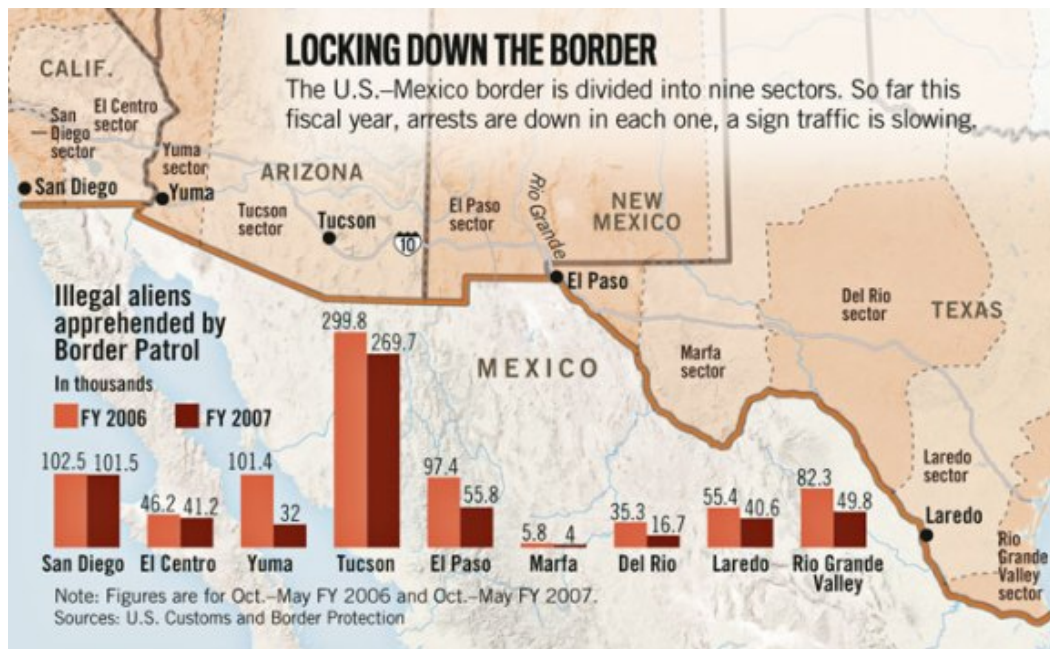


Figure 18: Illegal Aliens Apprehended by Border Patrol in FY 2006 and 2007

As more fences are built, DHS should coordinate current border efforts with Boeing, the contractor working on SBInet, to identify vibration or other technologies from various vendors or other agencies that can be installed underneath fences to detect underground tunneling activities. Such coordination should integrate tunnel detection technologies under fences with existing technologies that are being implemented with fences, sensors, or cameras above ground. It is not known which agency or company has an effective technology to be applied, but funding should be allocated to this important area of research.

Application of Technologies to Alternate Regions

While the primary focus of this report has been a case study of the U.S. borders with Mexico and Canada, the technological and support recommendations may be valid in other regions if a few factors are taken into consideration. These considerations are particular to the specific regions in question, and therefore a study of the areas of interest and tunneling risk is important.

Current Interests Abroad

The United States currently has interests in other nations where tunnels have been discovered or are suspected. As more covert operations take place in various countries of interest, many of these are taking place in tunnels and should thus be detected and monitored to ensure U.S. or allied interests are not threatened. These countries include, but are not limited to, Iraq, Afghanistan, Egypt and Israel (Gaza Strip), and Colombia. A more in-depth discussion of current interests in these countries follows. DoD needs tunnel detection technologies to identify tunnels in order to protect military bases, monitor movement of militants, terrorists, weapons, drugs, and other goods both along borders and within countries, and to ensure that prisons in foreign countries are secure. Detection technologies will prove useful in identifying underground facilities which conceal nuclear activities, caches of weapons, and command and control facilities. Specific tunnel detection recommendations vary between countries because of various terrains, environments, soils, and social, political, and military situations, but can be grouped according to these different characterizations.¹⁸⁹

Iraq

The U.S. has current interests in Iraq due to the war that began in 2003. Tunnels and underground bunkers have been found in the country since then. After much searching, Saddam Hussein was found in 2006 while hiding in a presidential bunker that included a

¹⁸⁹ Tucker, Robert E., Jason R. McKenna, Mihan H. McKenna, and Michael S. Mattice. "Detecting Underground Penetration Attempts at Secure Facilities." *Engineer* (Jan. – Mar. 2007). 27 Nov. 2007 <<http://www.wood.army.mil/ENGRMAG/PDFs%20for%20Jan-Mar%2007/Tucker.pdf>>.

“massive, two-level, network of tunnels and rooms estimated to be able to support upwards of 100 people for several months.”¹⁹⁰ U.S. soldiers have also located terrorists, rockets and rocket launchers, grenades, mortar rounds, small arms, and other weapons inside Iraqi tunnels and underground bunkers.¹⁹¹

On May 11, 2006, U.S. soldiers seized “a Katusha rocket, 10 rifle grenades, four mortar rounds, three IEDs and two mortar tubes from a tunnel complex.”¹⁹² On December 15, 2007, the U.S. military reported that a search operation northwest of Baghdad discovered tunnels with several heavy machine gun rounds inside them. Troops speculate al-Qaeda used the tunnels as enemy firing positions for anti-aircraft guns, as well as hiding places for al-Qaeda fighters after they launched attacks. These tunnels “were destroyed after air support was called in and two bombs were dropped on the target, which is the first of its kind in the central area controlled by U.S. troops.”¹⁹³

Afghanistan

The U.S. and other NATO countries have had interest in Afghanistan since the War on Terror began after the 9/11 terrorist attacks. Complex cave and tunnel systems were built in Afghanistan during the occupation of Soviet forces from 1979 to 1989 and have been expanded in recent years by Al Qaeda. Both during the Soviet invasion and currently, weapons and terrorists have been found in tunnels. Recently, coalition troops have searched hundreds of tunnels and caves.¹⁹⁴ In particular, a complex tunnel system was

¹⁹⁰ Hart, Bobby. “Medics Clear Rats From Saddam Hussein’s Bunker.” 26 Dec. 2006. American Forces Press Service. 11 Nov. 2007 <<http://www.defenselink.mil/news/newsarticle.aspx?id=2524>>.

¹⁹¹ “Iraqi Army, 2-7 Cavalry Take Down Insurgent Operation; Solve Murder, Uncover Large Weapons Cache.” 13 Feb. 2006. United States Central Command Headquarters. 11 Oct. 2007 <<http://www.centcom.mil/sites/uscentcom2/Lists/Current%20Press%20Releases/DispForm.aspx?ID=4537>>.

¹⁹² “Terrorists Killed, Hideout Destroyed.” 11 May 2006. United States Central Command Headquarters. 11 Oct. 2007 <<http://www.centcom.mil/sites/uscentcom2/Lists/Current%20Press%20Releases/DispForm.aspx?ID=3044>>.

¹⁹³ Deutsche Presse-Agentur. “At least 14 killed in Iraq - al-Qaeda tunnels found (Roundup).” 18 Dec. 2007. Middle East News. 18 Dec. 2007 <http://news.monstersandcritics.com/middleeast/news/article_1381952.php>.

¹⁹⁴ Grau, Lester. W. and Ali Ahmad Jalali. “Underground Combat: Stereophonic Blasting, Tunnel Rats and the Soviet-Afghan War.” *Engineer* (1998). 11 Nov. 2007 <<http://www.globalsecurity.org/military/library/report/1998/981100-underground.htm>>.

found at the Darunta Camp Complex in Jalalabad, Afghanistan, which was reportedly used for Osama bin Ladin's "Abu Khabab" camp. Coalition aircraft struck this complex in 2001.¹⁹⁵

Afghani tunnels are constructed largely in limestone and crystalline rock, but with the paired lack of geological maps of Afghanistan and the use of concealment mechanisms, tunnel and cave detection is difficult. Remote satellite imagery, specifically hyperspectral imagery, has revealed clues about the specific lithology of the arid region and thus assists troops who are often charged with finding and investigating tunnels and other underground complexes.¹⁹⁶

Egypt (Gaza Strip)

The Gaza Strip is currently one of the most hostile borders in the world and the U.S. is in negotiations with Egypt and Israel on issues like security, smuggling, and terrorists crossing the border. The Egypt-Gaza border is about 12.5 kilometers long; four of these kilometers are located alongside Rafah. Along the Rafah border, several smuggling tunnels (at least 90 entrance shafts) have been built to move militants, weapons, ammunition, and explosives from Egypt to Palestinian militants and Hamas, and vice versa.¹⁹⁷

Historically, after the 1979 international border Camp David treaty divided Rafah between Egypt and Gaza, smugglers dug tunnels for economic means like transferring cigarettes, alcohol, and drugs. Since fighting and the demand for weapons has increased, tunnels have now been used for smuggling military weapons, explosives, and other goods.¹⁹⁸

¹⁹⁵ "Afghanistan – Darunta Camp Complex." 21 Dec. 1999. GlobalSecurity.org. 27 Nov. 2007 <<http://www.globalsecurity.org/military/world/afghanistan/darunta.htm>>.

¹⁹⁶ Bahmanyar, Mir. *Afghanistan Cave Complexes 1979-2004: Mountain Strongholds of the Mjahideen, Taliban, & Al Qaeda*. Oxford, England: Osprey Publishing, 2004.

¹⁹⁷ "The Security Situation in Rafah." Oct. 2004. Human Rights Watch. 11 Nov. 2007 <<http://hrw.org/reports/2004/rafah1004/6.htm>>.

¹⁹⁸ Azoulay, Yuval and Mijal Grinberg. "IDF: 7 arms smuggling tunnels found under Gaza-Egypt border." 1 Nov. 2007. Haaretz.com. 18 Dec. 2007 <<http://www.haaretz.com/hasen/spages/919401.html>>.

The soil in Rafah consists mostly of a layer of dry, fine sand above wetter, silty clay which occurs about thirty to eighty feet below the surface. The distance between the topsoil and the groundwater is approximately 145 feet which makes tunnels fairly easy to construct. Below 145 feet, tunneling is difficult because pumping and an electrical supply are required under the groundwater table. Since tunnels built in dry sand will cave in without reinforcements, lumber and other materials are used to hold the sand in place.¹⁹⁹ Tunnels are also built air ventilation, lighting, and wiring which makes EM gradiometers easy to employ to detect these underground voids and improvements. The army has employed tunnel detection technologies along the border and confiscated explosive devices and neutralized them. Unfortunately, in May 2004, five U.S. soldiers were killed when an antitank missile hit an armored jeep while these operations were taking place.

Another remediation technique used by the IDF prior to Israel's withdrawal from the Gaza Strip in August 2005 included building a 10-meter-deep wall along part of the border and destroying homes where tunnel entrances were hidden. As a result, nearly 1,600 homes were destroyed in the Rafah camp.²⁰⁰

Soon, the U.S. Army Corps of Engineers and engineers from the Department of Defense will travel to Sinai to conduct an initial feasibility study and discuss the tunneling issue with the Egyptians. Recommendations have also included setting up a "trilateral security commission, composed of Israeli, Egyptian and American representatives," that would deal with Gaza-Egypt border issues, but currently, Israel opposes both the creation of such a commission and the proposal of Egypt stationing more soldiers along the border.²⁰¹

Colombia

A network of tunnels has also been found in Colombia. The tunnels have been used by the Revolutionary Armed Forces of Colombia (FARC) rebels in the past two years; they

¹⁹⁹ Chehab, Zaki. *Inside Hamas: The Untold Story of the Militant Islamic Movement*. New York: Avalon Publishing Group, 2007.

²⁰⁰ "The Security Situation in Rafah." Oct. 2004. Human Rights Watch. 11 Nov. 2007 <<http://hrw.org/reports/2004/rafah1004/6.htm>>.

²⁰¹ Ravid, Barak. "U.S. weighs plan to help Egypt block arms smuggling to Gaza." 17 Dec. 2007. Haaretz.com. 18 Dec. 2007 <<http://www.haaretz.com/hasen/spages/935133.html>>.

were discovered by the Colombian military. Their purpose is unknown at this time.²⁰²

The U.S. Department of State has identified Colombia as a base for Foreign Terrorist Organizations and President Alvaro Uribe has proposed continued law enforcement and military actions to defeat Colombia-based terrorist organizations.²⁰³ Juan Hurtado from USSOUTHCOM stated at the Surface Surveillance Technology Workshop in Boston, MA, in October 2007 that his command created a J9 interagency group to identify illegal border crossings and contraband.²⁰⁴

Since Colombia is one of the main international centers for drug production and trafficking and it is located in an area of heavy foliage coverage, studies are being conducted to test the feasibility of two technologies, ARTEMIS and TRACER, to penetrate triple canopy cover to find lines of communication and other objects with UAVs or Blackhawks. A foliage penetrating (FOPEN) study is being conducted by the Army Communications-Electronics Research, Development, and Engineering Center (CERDEC). Some problems to overcome are false alarms and the lower probability rate of detecting under foliage as compared to open areas. These technologies have promise for the future but are not currently mature enough for the deployment of tunnel detection technologies.²⁰⁵

Technology Implications

The USACE Tunnel Detection Team recommends a combination of tunnel detection technologies depending on soil type, subterranean infrastructure or debris, and other local factors. They include seismic sensors, electromagnetic induction, electrical resistivity,

²⁰² Magnuson, Stew. "Daunting Challenges Face Those Waging Subterranean Warfare." National Defense Feb. 2007. 27 Nov. 2007
<<http://www.nationaldefensemagazine.org/issues/2007/February/Dauntingchallenges.htm>>.

²⁰³ United States. Department of State. Office of the Coordinator for Counterterrorism. Country Reports on Terrorism 2006. Apr. 2007. State.gov. 29 Dec. 2007
<<http://www.state.gov/documents/organization/83383.pdf>>.

²⁰⁴ Anderson, Sean. Personal interview and email communication from Surface Surveillance and Technology Workshop at MIT. 25-26 Oct. 2007.

²⁰⁵ Anderson, Sean. Personal interview and email communication from Surface Surveillance and Technology Workshop at MIT. 25-26 Oct. 2007.

and ground penetrating radar (GPR).²⁰⁶ These techniques can be used from the surface or by placing sensors in boreholes, and may in the future be refined for use on UAVs.

Information collected from permanent sensors or mobile units must be analyzed at a central processing location. Appropriate communication networks should be set up to interface with troops or other interested personnel in these areas once gathered data suggests that a tunnel has been identified. Depending on local availability, wireless or satellite communication may be used to transmit the data, with wireless communication being preferred due to the high cost of satellite transmission.

Other factors should be considered when determining whether to use mobile ground methods or permanent sensors; these include the risk level, historical tunneling or smuggling occurrences, and political and military situations. Other issues to be examined with military personnel or governments regarding tunnels include:

- the interaction of fences and walls with tunnels, particularly along borders;
- effective human intelligence reporting methods;
- improved security measures above ground;
- power and communication requirements;
- personnel requirements maintenance and operation of equipment;
- data protection and security methods throughout the detection process;
- data analysis requirements;
- investigation, monitoring, and remediation logistics.

Applicability to Geological and Environmental Conditions

The technological recommendations put forth can be applied to a large range of areas with differing geological and environment conditions. In cases with large search areas similar to the U.S. border case, the tunneling risk assessment system should be employed to reduce costs and maximize the overall effectiveness of the system. Where conditions

²⁰⁶ “The Security Situation in Rafah.” Oct. 2004. Human Rights Watch. 11 Nov. 2007
<<http://hrw.org/reports/2004/rafah1004/6.htm>>.

preclude a full risk assessment, human intelligence should be analyzed to predict areas of long term high risk, areas of lower risk, and areas presenting no risk. As research and development continues, the technological solutions recommended should also improve in a number of soil types and under a variety of environmental conditions. Refinement in the area of noise suppression and filtering is likely to be the source of the most visible improvements. To maximize these refinements, it is optimal to set up site-specific testing facilities that mimic local conditions so that features specific to the area of interest can be recognized. Finally, consideration must be given to the level of available access to the area of interest. Where access is limited, consideration must be given to alternate deployment methods and the technologies which will be most likely to work with them.

Call for Additional Research

A critical component of the project team's recommendation includes research and development surrounding tunnel detection technologies. It is in fact, a pivotal part of our recommendation as a conditional factor for moving from Phase 1 implementation to Phase 2. None of the technologies presented are fully mature, and in fact many possess a great deal of room for improvement. In recommending further research and development, the team provides three stages which coincide with the overall recommendation for maximum efficiency. These stages include immediate research, intermediate research, and long term research.

Immediate Research (1-2 years)

In order to successfully rollout the recommended phase 1 implementation, research and development must have a narrow view. The items in need of immediate research include, designing a waterproof and concealable combinational motion/heat sensor for the Nogales and El Paso drainage systems, the development of the tunneling risk assessment system, and the layout of an implementation plan which accomplishes the goals laid out in phase 1. This research is all fairly straight-forward, funding must be put forth to accomplish the specific immediate goals necessary to implement phase 1. This research and development establishes the ground work necessary to promote more advanced research and development, by creating an excellent test bed, to be used for systematically testing the different technologies recommended.

Intermediate Research (2-5 years)

Intermediate research is a major phase in the progress towards creating a robust tunnel detection combinational solution, which will ultimately be used to secure the borders. After the immediate research fuels a phase 1 implementation of the recommendation, research must be done in order to move from phase 1 to phase 2. This research and the development resulting from it are classified in intermediate research. The immediate research and development will be the most costly and important. The overall goal of intermediate research is to verify and improve the technology employed in the phase 1 implementation until the performance is satisfactory for securing the areas of interest.

These technologies include passive and active seismic, electromagnetic induction, and ground penetrating radar. Emphasis should be placed on seismic and electromagnetic induction sensors due to their higher degree of use in the recommendation as well as their lack of maturity. There are a great number of enhancements which can be made to all of the technology recommended, with the proper funding and focus large strides can be taken in advancing these technologies. With this research there is no reason why the technological solutions cannot become more accurate and precise. One area of focus needs to be verifying and improving the tunnel location identification capabilities of each technology. This can be accomplished by utilizing the sensors to identify possible tunneling activity, then probing the suspect areas using a cone penetrometer, in order to verify the existence of a tunnel. At the point which the improvements yield results sufficiently verified to locate approximately all tunneling activity and tunnels, the intermediate research and development will be complete and phase 2 can be implemented.

Long Term Research (over 5 years)

The last phase of research in this three stage recommendation will provide extended funding for the refinement and any future developments of the technologies already implemented in phase 1 and phase 2. The refinement and development will be geared towards making these technologies more mobile and overall allow for these technologies to detect clandestine tunnels more efficiently. More importantly, the long term research will look into technologies that have not reached a high enough level of maturity to be implemented in phase 1 or phase 2, but show considerable promise for tunnel detection. This will also allow for emerging technologies to be researched and developed to a point that later on they could be implemented as well along the border in conjunction with the previously implemented technologies. This includes any technologies that are considered to be based on solid principles which could identify a tunnel including, but not limited to fiber optic seismic sensing, gravity gradiometry, and resistivity.

Other Areas for Research

One tunnel detection method that may warrant further research is satellite imagery. Satellite imagery can be used to detect traces of ground that have been disturbed to locate

tunnel entrance or exit points that are not inside homes or warehouses. Sources in the federal geospatial community have also noted that satellite imagery, as well as some sensors or unmanned aerial vehicles, can generate signatures such as temperature differences between soil above the ground and the adjoining ground to locate tunnel entrance or exit points. Satellite imagery was not identified as a primary detection method simply because the majority of tunnel entrances and exits are concealed within structures.

Additionally, research should be dedicated to funding for robots to search identified tunnels so less manpower is needed to search tunnels; using these to replace the “tunnel rats” from the Vietnam War era increases safety in places like the Nogales sewers. Robots “have been sent into caves in Afghanistan to check for insurgents, booby traps and weapons caches.” While no robot can yet fully operate perfectly like a human would, they have promise for the future.

Finally, in addition to research on the existing and emerging tunnel detection techniques, research into tunnel confirmation technology will be necessary. Research into tunnel confirmation was determined as falling outside of the scope of this project; additionally, much of the information required to carry out this research is classified. The development of these technologies will enable agents utilizing tunnel detection technologies to verify the location of an anomaly and correctly classify the anomaly. Several void and tunnel confirmation and verification technologies are currently being developed and tested.²⁰⁷

The authors recommend a concentration on the development and research of cone penetrometer testing (CPT), inert gas hyperspectrometry, and light detection and ranging technologies. While these three technologies have previously been tested for use in void verification, current research is currently not being pursued to a degree likely to produce timely results. By sponsoring research that aims to create a supplemental verification strategy for the recommended detection technology and deployment strategies, tunnel detection methods could see considerable refinement in a relatively short amount of time.

²⁰⁷ JTF-North. “JTF-North Support to Tunnel Detection Operations.” PowerPoint presentation. 10 Oct. 2007.

Conclusion

To conclude, tunnels are a threat, especially when used for human and drug smuggling and possibly WMD or terrorism. Since there is no silver bullet or any one technological solution for all areas susceptible to tunneling, the U.S. needs a proactive and holistic approach to tunnel detection with fixed sensors in high-risk, or urban areas, and mobile sweeps in lower-risk, or rural areas. Technologies have been recommended in combination with one another since each has its strengths and weaknesses. After installing sensors and operating tunnel detection equipment, sensor and change detection data can be integrated and analyzed for a high probability of detection. To continuously improve the technologies and data analysis, R&D and appropriate yearly funding is needed both in the short-term and long-term so the most effective solution is implemented and maintained. Tunnel detection technologies must also be complemented with effective policies, interagency cooperation, and enhanced cooperation with Mexico and Canada for an effective program to be successful. Our team believes that the recommendations in this report can be applied to other areas of interest around the world.

Limitations

The research for this project was primarily limited by two factors: classification level and time restraints. While a large amount of information on current tunnel detection technologies is classified, team members had access only to open-source, For Official Use Only (FOUO), and Law Enforcement Sensitive (LES). Because of this restriction, up-to-date information on technologies being used and researched may or may not be reflected in the recommendations provided. In addition, this project was limited to a timetable of four months for research, briefing, and report preparation. Additional time may have revealed beneficial information through additional travel and primary and secondary research, resulting in a more in-depth and conclusive report.

Appendix A^{208 209}

Total #	Date Found	#	Location	Length (ft)	Width (ft)	Height (ft)	Depth (ft)	Area Type	Activity
1	04/29/02	1	Imperial Beach, CA	65	4	6		rocky hillside	most likely drug activity
2	04/04/03	1	San Ysidro, CA	300 to 400	4	4	10	under POE	3,300 lbs of marijuana
3	07/02/04	2	San Ysidro, CA	20	3	3	3	150 yds from POE	unfinished
4	07/07/04	3	San Ysidro, CA	300	4	4	4.8	just west of POE	
5	01/09/06	4	San Ysidro, CA	35	2	2	4	25 yds from POE	
6	01/27/06	5	San Ysidro, CA	15	2	2	4	0.5 miles from POE	likely drugs and humans
7	02/09/06	6	San Ysidro, CA	23	2.5	2.5	1	200 yds from POE	
8	02/09/06	7	San Ysidro, CA	6.5			2	0.5 miles west of POE	
9	05/12/06	8	San Ysidro, CA	100	2.5	2.5	2	20 ft from POE	
10	05/16/06	9	San Ysidro, CA	30	3	3	1		
11	05/25/06	10	San Ysidro, CA	4	2.5	2.5	1	0.25 miles west of POE / 3 ft. south of the border fence	
12	09/26/06	11	San Ysidro, CA	103	2.5	2.5	4	parking lot of POE (M) to (would have been) parking lot (A)	
13	10/23/06	12	San Ysidro, CA	3	2.5	2.5	4	0.5 miles west of POE	
14	06/01/93	1	Otay Mesa, CA	1,452	5	4.5	30 to 70	warehouse to warehouse near Tijuana airport	likely drugs, Guzman
15	08/01/98	2	Otay Mesa, CA	50	2.5	3	10 to 40		
16	12/10/02	3	Otay Mesa, CA		10	10	59	under a house east of POE	drugs / connected to Arellano Felix
17	08/22/04	4	Otay Mesa, CA					east of POE, park to (probably) drain system (A)	DTO connection
18	11/16/05	5	Otay Mesa, CA	60	2 to 6	3	2	ends near sewage system (A)	
19	01/20/06	6	Otay Mesa, CA	90	2.5	2.5	4.5	0.5 miles west of POE built toward storm drain (A)	
20	01/24/06	7	Otay Mesa, CA	2,400	3	5	33	warehouse (M) to vacant building (A)	2 tons of marijuana discovered
21	01/31/06	8	Otay Mesa, CA	6			6	toward U.S. drainage system	
22	01/31/06	9	Otay Mesa, CA	3			3		
23	10/10/06	10	Otay Mesa, CA	120				drainage system linked to piping system, 0.25 from POE	human smuggling

²⁰⁸ JTF-North. "Border Tunnels." Excel spreadsheet. 24 Sept. 2007.

²⁰⁹ United States. Department of Homeland Security. Office of the Americas North America and Homeland Security Division. United States Cross Border Illegal Tunnels. Jul. 2007.

Total #	Date Found	#	Location	Length (ft)	Width (ft)	Height (ft)	Depth (ft)	Area Type	Activity
24	03/28/07	11	Otay Mesa, CA	8			6	1 mile from POE	
25	03/28/07	12	Otay Mesa, CA	2			4		
26	06/21/07	13	Otay Mesa, CA	31	3	3	3	300 yds east of POE	
27	02/01/02	1	Tierra Del Sol, CA	1250	4	4	65	fireplace to false floor	billions of \$ in narcotics moved
28	06/06/03	2	Tierra Del Sol, CA	40	3	7	15	well to (probably) vacant home	
29	12/03/07	3	Tierra Del Sol, CA	1,300-4,921	3 or 4	6	50		14,000 pounds of marijuana worth 5.6 million
30	09/12/03	1	Calexico, CA	330	1.5	4	14	ditch	Guzman or Zambada connection, drug and humans
31	11/12/03	2	Calexico, CA				12	tile business (M) to residential area (A)	likely rival of Arellano Felix cartel
32	02/25/05	3	Calexico, CA	590	3	5	15		likely drug related
33	09/15/06	4	Calexico, CA	400	3.33	3.5	9	bedroom to bedroom	skateboards likely used to help move drugs
34	09/01/95	1	Nogales, AZ	87	4	4		abandoned Methodist Church (A) to close to the POE (M)	
35	01/20/99	2	Nogales, AZ	138			12	storm drain to a home	
36	01/20/99	3	Nogales, AZ	153				same home as Nogales #2 and no exit was located	tunnel was built to fit a wagon?
37	10/21/99	4	Nogales, AZ	67	2	3		a home to a storm drain which leads to Grand Tunnel	drug trafficking
38	10/22/99	5	Nogales, AZ					a home to a storm drain which leads to Grand Tunnel	
39	05/16/00	6	Nogales, AZ					abandon store to storm drain and to the Grand Tunnel	marijuana drug traffic
40	06/29/00	7	Nogales, AZ	17				apartment to Morely Avenue wash	drug trafficking
41	02/26/01	8	Nogales, AZ	28			6	apartment to storm drain	drugs
42	09/04/01	9	Nogales, AZ	3			8	right next to the fence	
43	12/11/01	10	Nogales, AZ	84	3	3	25	reuse of Nogales #9	
44	01/21/02	11	Nogales, AZ					Grand Tunnel and would have connected to 401 storm drain	
45	04/15/02	12	Nogales, AZ	116	3	3	1	storm drain to storm drain and up through parking lot	drug trafficking
46	12/27/02	13	Nogales, AZ		3	3		building (M) to parking 6 ft north of border fence	drug trafficking
47	01/11/03	14	Nogales, AZ	12	3	3		grave (M) to a storm drain (M) / no border crossing	drug trafficking
48	09/12/03	15	Nogales, AZ	985	3	4	13	home to home	drug trafficking / Guzman / police chief arrested
49	11/18/03	16	Nogales, AZ		2	2		connects to drainage system	
50	03/01/05	17	Nogales, AZ	300	3	3	20	bar (M) to Grand Tunnel / 100 yds east of the POE	

Total #	Date Found	#	Location	Length (ft)	Width (ft)	Height (ft)	Depth (ft)	Area Type	Activity
51	03/15/05	18	Nogales, AZ	94	4	3 to 6		near the fence to (probably) a warehouse	
52	08/11/05	19	Nogales, AZ					no entrance to drainage system / no border crossing	
53	10/29/05	20	Nogales, AZ		2	2	3	home (M) into U.S. but unfinished	photo of drugs
54	10/31/05	21	Nogales, AZ					new branch of Nogales #10	drug trafficking
55	03/02/06	22	Nogales, AZ	150	3	3	4	storm drains	
56	03/04/06	23	Nogales, AZ	164	2.3	2.6	11.5	home (M) to unknown exit	drug trafficking / Guzman
57	01/06/07	24	Nogales, AZ					entrance/ exit unknown / probably did not cross border	
58	01/10/07	25	Nogales, AZ		2.5	2.5	20	abandoned home (A) / does not cross border	
59	02/08/07	26	Nogales, AZ	25	1.8	2.1	2	drainage system / no U.S. exit	
60	04/19/07	27	Nogales, AZ	20	2.5	2.5	2	apartment to Morely Tunnel	drugs
61	06/28/07	28	Nogales, AZ	300	3	3		home (A) to apartment (M)	thought to be drugs, but never recorded any activity
62	06/29/07	29	Nogales, AZ	4	0.833	0.833	18	warehouse to Grand Tunnel	drugs
63	07/11/07	30	Nogales, AZ	90	2	3	6	apartment (A) to drainage ditch/ system (M)	540 lbs of marijuana seized
64	07/29/07	31	Nogales, AZ	38	1.833	3.33	6	abandon building to Grand Tunnel	
65	09/07/07	32	<i>Nogales, AZ</i>	28	3	3	9		
66	09/23/07	33	<i>Nogales, AZ</i>	30	1.5	2	1		
67		34	<i>Nogales, AZ</i>						
68	05/01/99	1	Naco, AZ	260	4.5	5	15	mobile home (A) to house (M)	2,600 lbs cocaine, possible human smuggling
69	05/17/90	1	Douglas, AZ	220	3	5	30	home (M) to warehouse (A)	drug trafficking / Guzman
70	09/17/07	1	<i>San Luis, AZ</i>						
71	07/20/05	1	Lynden, WA	360	3.5	4	9.58	hut (C) to house (A)	drug trafficking

Note: Italicized rows indicate tunnels discovered after September 7, 2007

Note: (A) designates US, (M) designates Mexico, (C) designates Canada

Total #	Date Found	#	Location	Condition/ Appearance	How was the tunnel discovered
1	04/29/02	1	Imperial Beach, CA		
2	04/04/03	1	San Ysidro, CA	connected house (M) to drain (A)	drug truck smelled, located directly over drain
3	07/02/04	2	San Ysidro, CA	covered by a mattress	
4	07/07/04	3	San Ysidro, CA	same entrance as SY#1 / carpet, drainage, electricity	road depression
5	01/09/06	4	San Ysidro, CA	primitive	road depression, tunnel buckled
6	01/27/06	5	San Ysidro, CA	vacant lot (M) to storm drain (A), primitive	observation of tunnelers? truck sank?
7	02/09/06	6	San Ysidro, CA	connected to a ditch, not the first time discovered or filled	patrol observe depression? bus sank?
8	02/09/06	7	San Ysidro, CA	connect to flood control levee of the Tijuana River	
9	05/12/06	8	San Ysidro, CA	parking lot concealed with steel grate (A)	suspicious activity / possible sensor detection
10	05/16/06	9	San Ysidro, CA	near Mexican customs property	concrete truck created sinkhole
11	05/25/06	10	San Ysidro, CA		CBP and Grupo Beta
12	09/26/06	11	San Ysidro, CA	still under construction, those arrested were paid \$20 a night to dig	U.S. authorities video taped construction, notified Mexican authorities
13	10/23/06	12	San Ysidro, CA	crude	CBP and Mexican authorities
14	06/01/93	1	Otay Mesa, CA	lighting, ventilation, concrete, estimate \$1,000,000	found by Mexican authorities while investigating murder
15	08/01/98	2	Otay Mesa, CA	connected to OM #1	CBP vehicle sank
16	12/10/02	3	Otay Mesa, CA	unfinished, well supported, carts	revisiting old tunnel and found dead body inside
17	08/22/04	4	Otay Mesa, CA	unfinished, recently under construction	found by Mexican authorities while investigating murder
18	11/16/05	5	Otay Mesa, CA	crude, through concrete wall	San Diego Tunnel Task Force
19	01/20/06	6	Otay Mesa, CA	electricity	Mexican authorities acted on U.S. tip
20	01/24/06	7	Otay Mesa, CA	pulley system, lights, ventilation, water extraction system	San Diego Tunnel Task Force tip to Mexican Authorities
21	01/31/06	8	Otay Mesa, CA	crude, through concrete wall	Grupo Beta
22	01/31/06	9	Otay Mesa, CA	crude	Grupo Beta
23	10/10/06	10	Otay Mesa, CA	old oxygen pipe	patrol observed exit of individuals, informed others were still stuck
24	03/28/07	11	Otay Mesa, CA	crude, unfinished	information from arrested individual
25	03/28/07	12	Otay Mesa, CA	crude, unfinished	Mexican authorities discovered while investigating OM #11
26	06/21/07	13	Otay Mesa, CA	unfinished	Mexican Immigration Officer
27	02/01/02	1	Tierra Del Sol, CA	lighting, ventilation, rails and electric carts	Agent spotted false floor at pig farm
28	06/06/03	2	Tierra Del Sol, CA	unfinished	police discovered small hole
29	12/03/07	3	Tierra Del Sol, CA	improved	canine smelled drugs

Total #	Date Found	#	Location	Condition/ Appearance	How was the tunnel discovered
30	09/12/03	1	Calexico, CA	sophisticated, two carts, \$40,000 estimated construction	city workers found tunnel while digging sewage trench
31	11/12/03	2	Calexico, CA	lighting and ventilation	CBP vehicle sank
32	02/25/05	3	Calexico, CA	video surveillance, phone, air conditioning, electricity, ventilation	found by electronic means?
33	09/15/06	4	Calexico, CA	droplights, ventilation, water extraction system	JTF investigation
34	09/01/95	1	Nogales, AZ	crude, unfinished	10 month tunnel investigation
35	01/20/99	2	Nogales, AZ	crude, unfinished	Santa Cruz Metro Task Force
36	01/20/99	3	Nogales, AZ	electrical lights	same as #2? / tunnel was used at 3:30PM
37	10/21/99	4	Nogales, AZ	hand dug	Santa Cruz Metro Task Force investigation
38	10/22/99	5	Nogales, AZ	hand dug	suspicious activity / SC Task Force found while investigating #4
39	05/16/00	6	Nogales, AZ		Santa Cruz Metro Task Force
40	06/29/00	7	Nogales, AZ	hand dug, did not cross border	Santa Cruz Metro Task Force
41	02/26/01	8	Nogales, AZ	lights, no ventilation	
42	09/04/01	9	Nogales, AZ	unfinished	Mexican authorities
43	12/11/01	10	Nogales, AZ	rails with automotive crawler	
44	01/21/02	11	Nogales, AZ	later assessed Nogales #14, again	Nogales Sonora Municipal Police
45	04/15/02	12	Nogales, AZ	electricity	security noticed depression in employee parking lot
46	12/27/02	13	Nogales, AZ	crude, no structure support	
47	01/11/03	14	Nogales, AZ		Mexican investigation
48	09/12/03	15	Nogales, AZ	rail and carts, ventilation, and electric power	information from Mexican authorities
49	11/18/03	16	Nogales, AZ		Mexican authorities
50	03/01/05	17	Nogales, AZ	wood and steel support beams / later used with Nogales #22	CBP
51	03/15/05	18	Nogales, AZ	unfinished	CBP discovered while drilling a fence post
52	08/11/05	19	Nogales, AZ		Mexican authorities
53	10/29/05	20	Nogales, AZ	unfinished	CBP discovered when concrete collapsed
54	10/31/05	21	Nogales, AZ	concealed on Mexican side with cement	concerned citizen tipped off the CBP
55	03/02/06	22	Nogales, AZ	unfinished	CBP bike unit
56	03/04/06	23	Nogales, AZ		PGR located the tunnel while searching a Guzman residence
57	01/06/07	24	Nogales, AZ	unfinished, began to fill with raw sewage	ground collapsed during construction, revealing tunnel
58	01/10/07	25	Nogales, AZ	unfinished / does not link to sewage system	concern over noise in abandon home
59	02/08/07	26	Nogales, AZ	crude, hand-dug	GSA discovered while filling Nogales #12
60	04/19/07	27	Nogales, AZ		an apartment owner tipped off CBP
61	06/28/07	28	Nogales, AZ	lights, drainage pump, ventilation / does not connect to sewage system	ICE, DEA, and Mexican authorities
62	06/29/07	29	Nogales, AZ	crude, small	CBP canine unit
63	07/11/07	30	Nogales, AZ		car chase led to drug seizure and search of the apartment

Total #	Date Found	#	Location	Condition/ Appearance	How was the tunnel discovered
64	07/29/07	31	Nogales, AZ	ventilation, drop light	CBP discovered while patrolling the Grand Tunnel
65	09/07/07	32	<i>Nogales, AZ</i>	<i>improved</i>	<i>used a robot to explore tunnel</i>
66	09/23/07	33	<i>Nogales, AZ</i>		<i>ground collapsed</i>
67		34	<i>Nogales, AZ</i>		
68	05/01/99	1	Naco, AZ		ongoing multi-agency investigation
69	05/17/90	1	Douglas, AZ	hidden entrances, water pumps, rail and carts	ICE received information
70	09/17/07	1	<i>San Luis, AZ</i>	<i>improved</i>	<i>ground collapsed</i>
71	07/20/05	1	Lynden, WA	electrical power, reinforced with wooden beams and steel bars	CBSA investigation

Note: Italicized rows indicate tunnels discovered after September 7, 2007

Appendix B^{210 211}

	Drug Tunnels	Human Smuggling Tunnels	Ground Caved	Improved Tunnels	Electronic Means Used
San Diego Sector	Otay Mesa #1,3,4,7	Otay Mesa #10	Otay Mesa #2	Otay Mesa #1,3,7	San Ysidro #8 - sensors
	Imperial #1		San Ysidro #3,4,5,6,9	San Ysidro #1,3,4	
	San Ysidro #1,5			Tierra del Sol #1,2	
	Tierra del Sol #1,3				
Yuma Sector			San Luis #1	San Luis #1	San Luis #1 - Robot
El Centro Sector	Calexico #1,2,3,4	Calexico #1	Calexico #2	Calexico #1,2,3,4	Calexico #3 - electronic means
Tucson Sector	Douglas #1	Naco #1	Nogales #12,20,24,33	Douglas #1	Nogales #22 - Robot too big to fit
	Naco #1			Naco #1	
	Nogales #4,6,7,8,12,13,14,15,20			Nogales #3,8,10,12,14,	
	21,23,27,28,29,30			15,17,22,28,31,32	
Northern Border	Lynden #1			Lynden #1	

²¹⁰ JTF-North. "Border Tunnels." Excel spreadsheet. 24 Sept. 2007.

²¹¹ United States. Department of Homeland Security. Office of the Americas North America and Homeland Security Division. United States Cross Border Illegal Tunnels. Jul. 2007.

	Grand Drainage System	Morley Drainage System	Storm Drains	No Drain Accessed
Nogales Tunnels	#4,6,11,17,29,31,33	#24,27	#1,2,3,5,7,8,10,12,14, 16,19,21,22,26,30	#9,13,15,18,20,23,25,28,32,34

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About the Internship Project

This report was compiled by six University of Nebraska at Omaha students from August to December 2007. As project interns employed by the U.S. government through USSTRATCOM, they worked at the Global Innovation and Strategy Center (GISC) in Omaha, Nebraska, about 15-25 hours per week. They were restricted to a commercial network to research tunnel detection technologies and policy issues surrounding underground tunnels. The interns chose to conduct a case study of the U.S. borders with Canada and Mexico but they believe that their recommendations have applicability to other regions around the world.

After conducting primary research and visiting with several experts that spoke about unclassified material, the team analyzed several technologies and developed a combination of tunnel detection technologies for the ultimate recommendation. Recommendations regarding political, military, economic, social, information, and infrastructure issues were also made to support the recommended technologies. Two interns attended the third annual Border Management Summit in Washington, D.C. in October 2007, and three others visited the U.S. Army Corps of Engineers' Engineering Research and Development Center in Vicksburg, Mississippi, in November 2007 to learn about more about tunnel detection technologies.

Periodic progress briefings were presented to GISC employees during the duration of the project. The final briefing was presented numerous times to USSTRATCOM and other government employees, academia, and the private sector. The final report will be distributed to experts in the field and agencies concerned with tunnel detection.

About the Authors

Lance Tanner Allen is currently pursuing a master's degree in Architectural Engineering with an emphasis in Structural Design at the University of Nebraska at Lincoln. He received a bachelor's degree in Architectural Engineering from the University of Nebraska in May 2007. He has served as a member of the Nebraska Army National Guard since 2002 and worked as a Human Resources Specialist for the 1st Squadron of the 167th Cavalry in Lincoln, NE. After graduation in August 2008, he plans to become an Engineering Intern with a full-service architecture and engineering firm.

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Erica Tesla is currently pursuing an undergraduate degree in Physics at UNO. She has traveled abroad in India and worked at Cox Communications both in technical support and as a System Operations Center Coordinator. She has taught Physics courses at UNO since fall of 2005. After graduation in May 2008, she plans to pursue a graduate program in Science Writing at the Massachusetts Institute of Technology (MIT).